Greener Journal of Agricultural Sciences

ISSN: 2276-7770

Vol. 16(1), pp. 50-59, 2026

https://gjournals.org/GJAS

DOI: https://doi.org/10.15580/gjas.2026.1.031526037

Evaluation of advanced bread wheat Genotypes against dominance races of wheat stem rust under greenhouse conditions in Guji Zone, Southern Ethiopia

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ABSTRACT

Wheat (Triticum spp.) is one of the most important staple cereal crops cultivated for food worldwide including Ethiopia. Nevertheless, production and productivity of this crop is troubled by various factors, of which wheat stem rust caused by Puccinia graminis f.sp. tritici considered as the main diseases of wheat hindering the production. Hence, the study was aimed to evaluate the reaction of advanced bread wheat lines against virulent races. Forty four advanced bread wheat lines evaluated for their reactions against the dominant/virulent races TTKTT, TKTTF, TTTTF, TKKTF, and TTRTF. Ten advanced bread wheat lines, namely; ETBW-164008, ETBW-17.148, ETBW-9452, BW-17-2020, BW-17-4018, ETBW-17-133, BW-164006, BW-17-4456, BW164002 and BW-164004 showed resistance reactions (IT = fleck (;) to 2) to all dominant races. Though, to come up with a precise and reliable recommendation, the experiment should be done at adult stage resistance and the evaluated lines should be used for the future breeding program.

ARTICLE'S INFO

Article No.: *031526037*
Type: *Research*
Full Text: *PDF, PHP, HTML, EPUB, MP3*
DOI: ***10.15580/gjas.2026.1.031526037***

Accepted: *16/03/2026*
Published: *23/03/2026*

Keywords: *Virulent; Races; Dominant; Advanced lines*

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Article's QR code

INTRODUCTION

Wheat (Triticum spp.) is one of the most important and major cereal crops in the world in terms of production and nutritional value. Wheat is the leading source of cereal proteins and primary staple food (Figueroa *et al*., 2017). It is the 2nd most important crop in the world next to rice (Ambika and Meenakshi, 2018). Its sources of food for human and livelihood for over one billion people in developing countries (FAO, 2020). It is one of the most important crops for human nutrition, due to 60-70 % of starch content in the grain as well as considered as the main source of calories for human diet (Shewry, 2009). Globally, wheat is cultivated on over 787 million hectares of land with a production of about 774.9 million metric tons (FAO, 2021), with an average productivity of around 3.56t ha^{-1} with high variability among countries and regions (FAO, 2021). It grows from an altitude of 1500 to 3000 m.a.s.l (White *et al*. 2001), the most suitable areas for bread wheat production ranges from 1900 to 2700 m.a.s.l (Gebre Mariam, 1991).

Ethiopia is the largest wheat producer in sub-Saharan Africa (Tadesse *et al*., 2018). In Ethiopia, wheat is one of the most important cereal crops cultivated and considered as the most important strategic food security crops, which is largely grown in the mid and highlands of the country (Beyene *et al*., 2016). It ranks 3rd after tef, maize, and sorghum in area coverage and 2nd in total production after maize and teff (CSA, 2021). The national average productivity in Ethiopia is estimated to be 3.09t ha^{-1} (CSA, 2021) with low productivity as compared to the global average yield which was 3.56 t ha^{-1}(FAO, 2020).

According to CSA (2021), the major wheat producing regions in Ethiopia include Oromiya, Southern Nations Nationalities and Peoples' Region (SNNPR), Amhara & Tigray. Smallholder production meets more than 70% of the national consumption demand (Shiferaw *et al*., 2011). In Orimiya region of Guji zone wheat is the most important cereal crop next to tef and barley with average yield of 2.4t ha^{-1} (CSA, 2020) as compared to national average 3.09t ha^{-1} (CSA, 2021). However, the harvested yield still is found low compared to national and global average production (CSA, 2021).The low productivity of wheat is principally due to the biotic and abiotic stresses that are increasing in intensity and frequency associated which climate change (Tadesse *et al*., 2018).

In Ethiopia, more than 30 fungal diseases of wheat have been identified (Fekadu *et al*., 2004). Rust diseases: stem rust (*P. graminis* f sp. *tritici*), leaf rust (*P. triticina*), and yellow rust (*P. striiformis* f.sp. *tritici*) were reported as the major biotic wheat production constraints and stem rust causes up to 70.7% yield losses (Netsanet *et al*., 2017). According to Singh *et al.* (2006) the highland of Ethiopia is considered as a "*hot spot*" for the epidemics of wheat stem rust diversity. The high virulence diversity and evolution rate of the pathogen puts a considerable proportion of wheat germplasm at risk (Abebe *et al*., 2012). Effective management of stem rust requires a coordinated effort, including race monitoring, collection and characterization of sources of resistance and resistance breeding (Boshoff *et al*., 2000). Physiological races prevalent in the central highlands of Ethiopia are among the most virulent in the world (Abiyot *et al*., 2014).

Moreover, some studies that were carried out in Ethiopia indicated that most previously identified races were virulent on most of the varieties grown in the country and they are among the most virulent in the world (Admassu *et al*., 2009). Nevertheless, recent information is scarce about virulence pattern of wheat stem rust races around Guji zone and was investigated in the current study. This study was also investigated the current virulence degrees of *Pgt* of wheat in Guji zone, and it's association with advanced breeding lines, thereby rendering the busting wheat cultivars producing in the country for sustainable production. In Guji zone wheat stem rust was reported as a serious disease of wheat production and may cause high economic losses (Tolesa *et al*., 2014). Although Guji zone is one of the wheat producing areas in the country, but there was limited information regarding to the distribution, incidence, and severity of the wheat stem rust and the physiological races of *Pgt*.

Therefore, knowing the pathogens their virulence pattern, and variability is paramount in the management strategy of the pathogen (Duveiller *et al*., 2007). Currently, most of the released commercial bread wheat varieties by the national wheat research program frequently defeated by new races of stem rust. There was a need for producers to use improved wheat genotypes possessing high resistance to emerging new physiological races of *Pgt* by screening of advanced wheat lines at seedling stage. Therefore, this study was designed based on the following objective:

- ❖ Evaluate the advanced bread wheat genotypes against dominance races of wheat stem rust under greenhouse conditions

MATERIAL AND METHODS

Description of the Study Areas

Wheat stem rust disease survey and crop sample collection were conducted in the Guji zone, Oromiya regional state during the 2020 main cropping season across major wheat producing districts (Anna Sora, Bore and Dama). Those districts were considered as the "hot spot" for wheat stem rust in the previous report (Tolesa *et al*., 2014).

Evaluation of Advanced Wheat Bread Lines to Races of Stem Rust under Greenhouse Conditions

The evaluations of advanced bread wheat lines to the identified races were done at Ambo Agricultural Research Center, (from May 2020 to January 2021) by followed below procedures.

Description of stem rust races used for seedling stage evaluation

The spores of stem rust races diagnosed in the present race analysis study and previously identified in Ethiopia (Netsanet *et al,*. 2017) were multiplied on the McNair and collected in separate test tubes for inoculation of the wheat varieties. The races included (TKTTF, TKKTF, TTTTF, TTKTT and TTRTF) were used to test the lines.

Table 1: Description of stem rust races used for seedling evaluation

Race	Virulence	Avirulence	Detected year
TKTTF	*5,21,9e,7b,6,8a,9g, 36,30.17,9a,9d,10,Tmp, 38, McN*	*11,24,31*	2013
TTTTF	*5,21,9e,7b,11,6,8a,9g, 30,17,9a,9d,10,Tmp, 38, McN*	*24,31*	2017
TTRTF	*5,21,9e,7b,11,6,8a,9g, 17,9a,9d,10,Tmp, 38, McN*	*30,24,31*	2017
TTKTT	*5,21,9e,7b,11,6,8a,30.17,9a,9d,10,Tmp,24,31,38,McN*	*36*	2020
TKKTF	*5,21,9E,7b,6,8a,9g, 30.17,9a,9d,10,Tmp, 38, McN*	*11,36,24,31*	2019

Evaluated advanced bread wheat lines under greenhouse condition

A total of 44 advanced bread wheat lines including susceptible reference variety called "Mc Nair" and three standards checks (Digelu, Ogolcho and Kubsa) were used (Table 6). Advanced bread wheat lines were obtained from Kulumsa Agricultural Research Center (KARC) and standard checks were obtained from Ambo Agricultural Research Center (AARC).

Table 2: Lists of advanced bread wheat lines (n=40) with their corresponding Origin/pedigree and standard checks (n=4) used in the evaluation against stem rust races reaction.

Advanced wheat lines	Pedigree	Sources	Reactions
BW16401	NADIA-1/AKRAM	KARC	S
ETBW17-134	NELOKI*2//KFA/2*KACHU	KARC	MS
ETBW17-175	SUP152*2/HAWFINCH #1/3/2*KACHU #1/KIRITATI//KACHU	KARC	MS
BW 164008	HUBARA-8/3/MUNIA/ALTAR84//MILAN/4/ANGI-2/5/YAMAMA/SD 8036	KARC	MR
ETBW 17-148	QUAIU/5/FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/6/2*WBLL1*2/BRAMBLING/5/BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ	KARC	R
ETBW-8583	MINO/898.97/4/PFAU/SERI.1B//AMAD/3/KRONSTAD F2004	KARC	MS
ETBW 9547	MUTUS*2/AKURI//MUTUS*2/TECUE #1	KARC	MS
BW 164009	MOUKA-4/RAYON//SIDS-12/5/SERI.1B//KAUZ/HEVO/3/AMAD/4/KAUZ/FLORKWA-1	KARC	MS
BW 174457	FLORKWA-2/85 Z 1284//ETBW 4920/3/LOULOU-18	KARC	MS

ETBW-17-193	BECARD#1/5/KIRITATI/4/2*SERI.1B*2/3/KAUZ*2/BOW //KAUZ*2/6/KFA/2*KACHU	KARC	MS
ETBW-9651	KACHU#1/4/CROC_1/AE.SQUARROSA (205)//BORL95/3/2*MILAN/5/KACHU*2/6/KFA/2*KACH U	KARC	MS
ETBW-17-143	REBWAH-19/HAAMA-14	KARC	R
ETBW-9452	REBWAH-19/HAAMA-14	KARC	R
ETBW 172020	NELOKI/5/FRET2/KUKUNA//FRET2/3/TNMU/4/FRET2* 2/SHAMA/6/KINGBIRD #1//INQALAB 91*2/TUKURU	KARC	R
ETBW174018	CHAM-4/MUBASHIIR-9	KARC	R
ETBW-17-50	NGL//2*WHEAR/SOKOLL	KARC	R
ETBW-17-214	W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1*2/5/SA UAL/YANAC//SAUAL	KARC	MS
ETBW-164013	MILAN/KAUZ//HD29/2*WEAVER/3/MILAN/PASTOR/4/ REYNA-4	KARC	MS
ETBBBW-17-174	SUP152*2/HAWFINCH #1/3/2*KACHU #1/KIRITATI//KACHU	KARC	MS
ETBW-17-79	KS82W418/SPN/3/CHEN/AE.SQ//2*OPATA/4/FRET2/5 /2*SOKOLL/3/PASTOR//HXL7573/2*BAU	KARC	MS
ETBW-172233	KFA/2*KACHU/4/WBLL1*2/KURUKU//KRONSTAD F2004/3/WBLL1*2/BRAMBLING	KARC	MS
ETBW-9655	WBLL1/KUKUNA//TACUPETO F2001/3/BAJ #1*2/4/KINGBIRD #1	KARC	MS
ETBW-9136	92.001E7.32.5/SLVS/5/NS-732/HER/3/PRL/SARA//TSI/VEE#5/4/FRET2/6/SOKOL L/3/PASTOR//HXL7573/2*BAU	KARC	MS
ETW-17-133	SW89.5277/BORL95//SKAUZ/3/PRL/2*PASTOR/4/HEI LO*2/5/BLOUK #1//WBLL1*2/BRAMBLING	KARC	MS
EETBW-9547	MUTUS*2/AKURI//MUTUS*2/TECUE #1	KARC	R
ETBW-17-2289	SOKOLL/WESTONIA	KARC	R
ETBW-9065	FALCIN/AE.SQUARROSA(312)/3/THB/CEP7780//SHA 4/LIRA/4/FRET2/5/DANPHE#1/11/CROC_1/AE.SQUAR ROSA (213)//PGO/10/ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/T RM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA	KARC	MS

ETBW-9650	SOKOLL/3/PASTOR//HXL7573/2*BAU/4/GLADIUS	KARC	MS
ETBW- 164010	HIDDAB/ATTILA-7//GIZA-168/3/Sids-4	KARC	MS
ETBW-9545	ATTILA*2/PBW65*2//MURGA/4/MUU #1//PBW343*2/KUKUNA/3/MUU/5/ATTILA*2/PBW65//MURGA	KARC	MS
ETBW-9657	CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/HAR311/6/PBW343*2/KUKUNA*2//FRTL/PIFED/7/CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/HAR311	KARC	MS
ETBW-9641	MELON//FILIN/MILAN/3/FILIN/4/PRINIA/PASTOR//HUITES/3/MILAN/OTUS//ATTILA/3*BCN/5/MELON//FILIN/MILAN/3/FILIN	KARC	MS
ETBW-164011	NADIA-1/AKRAM	KARC	MS
ETBW-17-199	KAUZ*2/MNV//KAUZ/3/MILAN/4/BAV92/5/HEILO/6/CHIBIA//PRLII/CM65531/3/SKAUZ/BAV92/7/2*KFA/2*KACHU	KARC	MS
ETBW-164002	HUBARA-5/PASTOR-2/6/88ZHONG218//CTK/VEE/3/KVZ/GV//PR/4/KRASNOVODOPADSKAYA25/5/KS82117/MLT	KARC	S
ETBW-164004	CHAM-6/SHUHA-14//SOMAMA-3/3/SOONOT-7	KARC	R
ETBW-9080	KACHU//WHEAR/SOKOLL	KARC	R
ETBW-9128	FRNCLN*2/BECARD	KARC	MS
Digelu	SHA7/KAUZ	AARC	MS
Ogolcho	SOKOLL/EXCALIBUR	KARC	MS
Kubsa	YANAC/3/PRL/SARA//TSI/VEE#5/4/CROC-1/AE.SQUAROSA(224)//OPATTA	AARC	MS
Mc nair	KIRITATI//2*PBW65/2*SERI.1B	KARC	S

Planting of advanced bread wheat lines and inoculation

Five seeds of each advanced wheat lines and susceptible checks were planted in 5 cm diameter plastic pots separately using Completely Randomized Design (CRD) in the greenhouse with three replications. Seven-day-old seedlings (the first leaf is fully expanded and the second leaf is just emerged to grow), were inoculated with spores of detected races from study area (approximately 4-5 mg spores per 1ml lightweight mineral oil suspension). For incubation, inoculated plants were moistened with fine droplets of distilled water by using atomizer after 30 minutes of inoculation. Seedlings placed in a dew chamber for 18 hrs dark period at 18- 22℃ and 98-100% relative humidity (RH) followed by exposure to light at least for 3-4 hrs to provide a favorable condition for stem rust infection. Seedlings were then allowed to dry/remove their dew/moisture for about 1-2 hrs. Following this, the seedlings were transferred from dew chamber to glass compartments in the greenhouse where conditions are regulated at 12 hrs photoperiod, and a temperature range of 18- 25℃ and RH of 60-70%.

Planted advanced wheat lines seedling for inoculation

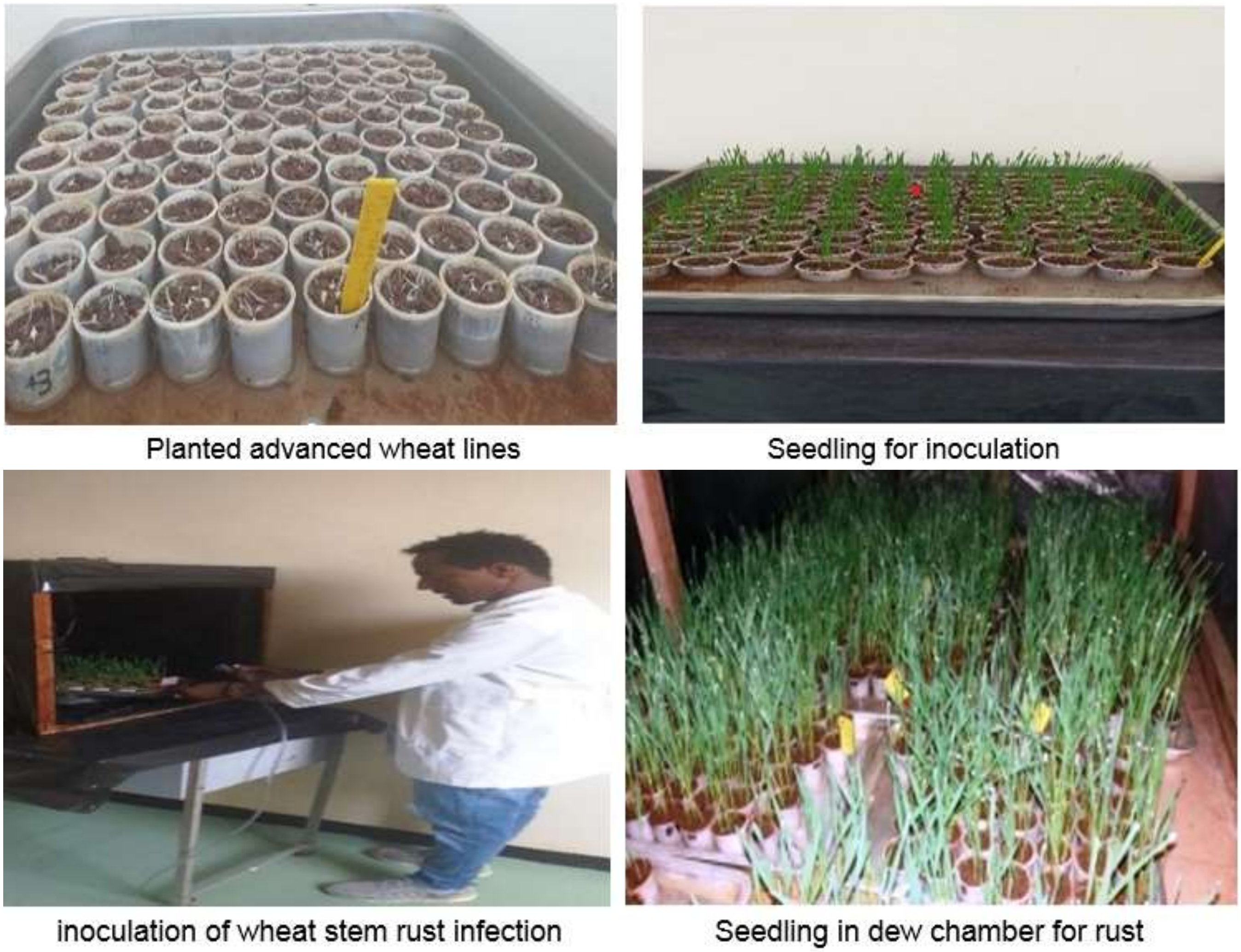

Figure 1. Procedure of inoculation wheat stem rust and occurrence of infection process

Disease assessment and collected data

Disease assessment was carried out 14 days after inoculation using the 0 to 4 infection type (IT) scoring scale (Stakman *et al*., 1962) (Figure 1). Infection types 0 to 2+ were regarded as incompatible (low infection types), whereas infection types 3 to 4 were considered as compatible (high infection types).

Figure 2. Susceptible wheat line seedling

Figure 3. Resistant wheat line seedling

Data Analysis

Greenhouse evaluation of advanced bread wheat lines were computed on the Microsoft excel by using the descriptive statistical analysis.

RESULT AND DISCUSSION

Evaluation of Advanced Wheat Bread Lines for Reaction to Virulent Races of Stem Rust under Greenhouse Conditions

A total of 44 advanced wheat line including reference varieties (Digelu, Ogolcho, Kubsa and McNair were tested at seedling stage. The infection types (ITs) of stem rust on wheat lines evaluated at seedling stage are presented in (Figure 2). Susceptible controls McNair was heavily infected and exhibited the expected compatible ITs ranging from 3- to 3 for all stem rust races. This infection type indicated successful inoculation and high level of infection in each experiment. This in turn allowed for the reliable scoring of ITs in all wheat genotypes.

The greenhouse evaluation had shown that advanced bread wheat lines differed in their reaction to the dominant stem rust races; TTKTT, TKTTF, TTTTF, TKKTF and TRTTF. Out 44 of advanced bread wheat lines evaluated at the seedling stage, none showed complete resistant (zero IT) while 10 (ETBW-164008, ETBW-17148, ETBW-9452, ETBW-172020, ETBW-174018, ETBW-17-133, ETBW-164006, ETBW-17-4456, ETBW-164002 and ETBW-164004) had resistant infection types (IT = ";" or fleck to; 1^+). The resistance reaction in these lines implied the presence of seedling resistance gene towards these virulent races. Nine advanced bread wheat lines namely; ETBW-8583, ETBW-17-214,ETBW-17-2233, ETBW-9080, ETBW-9065 ETBW-9651, ETBW-9655, ETBW-9655 and ETBW-9545 exhibited resistance to TTKTT virulent race might have *sr36* but susceptible to TTTTF, TKTTF, TKKTF and TTRTF races (IT=3-). The incompatible reaction of these lines to TTKTT race and compatible reaction to TTTTF, TKTTF, TKKTF and TTRTF races this indicateds the presence of unidentified seedling resistance gene in these particular lines.

Among the 44 bread wheat lines evaluated, 22 (ETBW-16401, ETBW-17-175, ETBW-8583, ETBW-9547, ETBW-164009, ETBW-17-4457, ETBW-17-193, ETBW-17-50, ETBW-164013, ETBE-1779, ETBW-17-174, ETBW-9650, ETBW-164010, ETBW-9657, ETBW-9641, ETBW-164011, ETBW-17-199, ETBW-9128, Digelu, Ogolcho, Kubsa and McNair showed susceptible reaction (3- to 3+) to all selected virulent races TTKTT, TKTTF, TTTTF, TKKTF and TRTTF (Table 17). Seedlings of ETBW-17143 and ETBW-1779 were resistant to TKTTF and TKKTF races (";" to 2+), however, they were susceptible to TTKTT, TTTTF, and TTRTF races. This could be due to the broadest virulence spectrum of the current races.

Table 3: Reactions of advanced bread wheat lines against dominant stem rust races at seedling stage in the greenhouse

Advanced bread wheat lines	Seedling Reaction (IT)				
	TTKTT	TKTTF	TKKTF	TTTTF	TTRTF
ETBW16401	3^-	3^-	3^-	3^-	3^+
ETBW17-134	3^-	3^-	3^-	3^+	3^-
ETBW17-175	3^-	3^-	3^-	3^-	3^-
ETBW 164008	;1	$;1^+$	;1	;1	$;1^+$
ETBW 17-148	$;1^+$	$;1^+$	;1	$;1^+$	;1
ETBW-8583	2^-	3^-	3^-	3^+	3^-
ETBW 9547	3^+	3^-	3^-	3^-	3^-
ETBW 164009	3^+	3^-	3^-	3^-	3^-
ETBW 174457	3^+	3^-	3^-	3^-	3^-
ETBW-17-193	3^-	3^+	3^-	3^-	3^-
ETBW-9651	2	3^-	3^-	3^-	3^-
ETBW-17-143	3^-	3	3	3^-	3^-
ETBW-9452	$;1^+$	$;1^+$	;1	;1	$;1^+$
ETBW- 172020	;1	;1	;1	$;1^+$	$;1^+$
ETBW174018	;1	;1	$;1^+$	$;1^+$	$;1^+$
ETBW-17-50	3^-	3^-	3	3^-	3^-
ETBW-17-214	$;1^+$	3^-	3	3^-	3^-
ETBW-164013	3^-	3^-	3^-	3^-	3^-
ETBW-17-174	3	3	3^-	3^-	3^-
ETBW-17-79	2	2	2^+	3^-	3^-
ETBW-172233	$;1^+$	3^-	3^-	3^-	3^-
ETBW-9655	2	3^-	3^-	3^-	3^-
ETBW-9136	;1	$;1^+$	$;1^+$	3^-	3^-
ETBW-17-133	;1	;1	$;1^+$	$;1^+$	$;1^+$
ETBW-9567	3^-	3^-	3^+	3^-	3^-
ETBW 164006	$;1^+$	$;1^+$	;1	$;1^+$	$;1^+$
ETBW-174456	;1	;1	$;1^+$	$;1^+$	$;1^+$
ETBW17-2289	3^-	3	3^-	3^-	3
ETBW-9065	$;1^+$	3	3^-	3^-	3^-
ETBW-9650	3^-	3^-	3	3^-	3^-
ETBW-164010	3^-	3^-	3^-	3^-	3^-
ETBW-9545	;1	3^-	3^-	3^-	3^-
ETBW-9657	3^-	3^-	3^-	3^-	3^-
ETBW-9641	3	3	3	3^+	3^-
ETBW-164011	3^-	3^-	3^-	3^-	3^-
ETBW-17-199	3	3^-	3^-	3^-	3^+
ETBW-164002	$;1^+$	$;1^+$	$;1^+$	$;1^+$	;1
ETBW-164004	$;1^+$	$;1^+$	$;1^+$	$;1^+$	$;1^+$
ETBW-9080	;1	3^-	3^-	3^-	3^-
ETBW-9128	3^-	3	3^-	3^+	3^-
Digelu	3^-	3^-	3^-	3^-	3^-
Ogolcho	3	3^-	3^-	3^-	3^-
Kubsa	3^-	3^-	3	3^-	3^-
Mc Nair	3	3	3	3	3

*The scale described by Stakman *et al*. (1962) with ITs; 1, 2 considered resistant and 3, 4 considered susceptible. Negative (-) = smaller uredinia than the normal size and + larger than the normal uredinia

ETBW-1779 and ETBW-17-143 were resistant to TKTTF race while ETBW-17-143 was resistant to TKKTF. Infection type coding resistance was ranging from; (**-** flecks) to (2+) were regarded as resistant whereby the frequent infection type mostly displayed was ";1" on the primary leaves of the seedling.

Moreover high frequency of 22.2% of advanced bread wheat lines were resistant TTKTT, TKTTF, TTTTF, TKKTF, and TTRTF races, with low infection types ranging from (flecks) to (2), as well as 20.5% of bread wheat lines resistant to TTKTT race with low infection types (2). In Ethiopia devising a breeding strategy to develop stem rust-resistant wheat varieties is valuable and will definitely contribute to the stability of wheat production in the country. Several efforts were made towards resistant cultivars development in the country and many bread wheat cultivars with various levels of rust resistance were released for production. However, most of the released bread wheat varieties overcome to stem rust soon after their release due to either introduction of exotic races or evolvement of new local races and changes in environmental factors (Wubishet and Chemeda, 2016).

According to Ambika and Meenakshi (2018), the changing temperature and rainfall patterns have encouraged the emergence of new stem rust races and the currently resistant and popularly grown wheat varieties remain at constant stake of losing their resistance to it. In this study, none of the tested lines were immune to stem rust infection. Out of the tested advanced bread wheat lines and varieties, some wheat lines recorded low infection types (fleck (;) to 2). These could be due to these lines carry effective race-specific or seedling stem rust resistance genes to the virulent races. According to Sheikh *et al*., (2017), seedling stage 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. Seedling resistance can be very powerful and can sometimes offer the plant near immunity against a specific race of the pathogen. This is the reason that seedling type of resistance 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 inoculum (Hulbert and Pumphrey, 2014).

Ogutu *et al*. (2017) also reported cultivars that exhibited 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. Major gene resistance/seedling resistance can offer complete protection and significant economic benefits to farmers. Therefore, these varieties can be used as sources of stem rust resistance when the aim of the breeding program is for the major gene (Cheruiyot *et al.*, 2015)

CONCLUSION

Five dominant races; TTKTT TKTTF, TTTTF, TKKTF, and TTRTF were inoculated on 44 advanced bread wheat lines at seedling stage to evaluate their seedling reaction to stem rust. The results revealed that there was no complete resistance (zero infection type) observed among the evaluated advanced bread wheat lines. However, ETBW-164008, ETBW-17.148, ETBW-9452, ETBW-17-2020, ETBW-17-4018, ETBW-17-133, ETBW-164006, ETBW-17-4456, ETBW164002 and ETBW-164004 showed resistance reactions (IT = fleck (;) to (2) to all dominant races at seedling (or all-stage) resistance. Therefore, they can be used as source of resistance at adult stage resistance in wheat breeding program.

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Cite this Article: Girma, T (2026). Evaluation of advanced bread wheat Genotypes against dominance races of wheat stem rust under greenhouse conditions in Guji Zone, Southern Ethiopia. *Greener Journal of Agricultural Sciences*, 16(1): 50-59, https://doi.org/10.15580/gjas.2026.1.031526037.