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PHENOTYPIC EVALUATION OF ADVANCED BREAD WHEAT GENOTYPES FOR THE RESISTANCE TO STRIPE (YELLOW) RUST (PUCCINIA STRIIFORMIS F.SP. TRITICI) IN ETHIOPIA

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ABSTRACT
Ethiopia’s government has commitment to achieve wheat self-sufficiency through initiatives of wheat are expansion, irrigation development and management of yield gaps caused by biotic factors especially wheat rusts. Wheat yellow (stripe) rust caused by Puccinia striiformis f.sp. tritici (Pst) is regular production constraint with high epidemics and evolving of new race in the world especially in East Africa embracing the Ethiopian wheat production. Acquaintance and recognizing of resistant wheat genotypes at adult plant stage to yellow rust disease have special significance to manipulate genetic resistance that reduce cost of production for the fungicides and its application, and frequency of serious epidemics to enhance wheat production in Ethiopia. Thus, utilization of host plant resistance is the preeminent and successful tactics to meet the needs of wheat producers. Hence, the present research was implemented with objective of examining the novel sources of advanced bread wheat genotypes for the resistant to wheat yellow (stripe) rust at dedicated screening sites.
A total of 1166 wheat genotypes sourced 606, 452, 95 and 13; from local cross, CIMMYT and ICARDA introductions, and commercial cultivars were evaluated at both Bekoji and Meraro dedicated yellow rust nursery screening sites. Of the tested genotypes 96, 72, 20 and 3 materials were performed best and selected for the resistance to yellow rust in dedicated screening nursery sites that were sourced from local cross, CIMMYT and ICARDA and commercial varieties respectively. Thus, selected genotypes with better level of durable resistance could be incorporated in crossing blocks to develop resistant wheat varieties in order to improve the future wheat breeding program of Ethiopia.

KEY WORDS
Stripe rust, dedicated nursery, resistant genotypes, durable resistance.

Wheat is the most widely cultivated cereal crop under wide range of climatic conditions and geographical regions with more than 220 and 2.1 million hectors in the world and Ethiopia respectively (Shiferew *et al*., 2008; Singh *et al*., 2011; Wuletaw *et al*., 2022).With growing demand due to rapid increase of population the government of Ethiopia is committed to achieve wheat self-sufficiency and to save the scarce foreign currency reserve spent on import through initiatives of wheat area expansion, irrigation development and managing yield gap closure limited by biotic and abiotic factors (Senbeta and Worku, 2023). However, In Ethiopia enhancing of wheat production and productivity is faced by climatic and green bridge factors which favor increasing of recurrent epidemics of wheat rusts diseases that attacks resistant varieties and hindered the global wheat production as the domestication of the crop and continue to threaten the world’s quantity and quality of wheat.

Wheat rusts are highly mobile, extremely destructive, regularly changing and trans-boundary increasing treats and wind born dispersal of fungal diseases. Under favorable condition wheat rusts are capable of causing 100% yield loss with in the weeks that majority of wheat cultivars are either susceptible or have to low level of resistance to the disease. Among the wheat rusts , wheat stripe (yellow), stem (black) and leaf (brown) rusts caused by *puccinia striiformis* f.sp.*tritici (Pst), puccinia graminis f.sp.tritici (Pgt)* and *pucinia triticina (Pt)* respectively, are an obligate bio-trophic parasitic fungal pathogens that are completely dependent on nutritional resources obtained from living host plants for growth and reproduction (Duplisis *et al*., 2012).

stripe (yellow) rust is a serious wheat production problem at early growth stage and continue to develop during the developmental stage of the crop in highly prevalent with cool and wet weather conditions in all continents where wheat is grown (Afzal *et al*., 2007; Chen *et al*., 2014).Currently, wheat stripe rust is the most economically important fungal disease caused with 100% yield loss and quality degradation particularly in susceptible cultivars (Badebo *et al*., 2001;Milus *et al*., 2008; Chen, 2015; Ayele and Muche, 2019), indeed approximately 88% of wheat varieties in the world is susceptible to *puccinia striiformis* f.sp. *tritici* and global losses annually affected US$ 1 billion by the disease (Beddow *et al*., 2015). Newly, recurrent aggressive *Pst* races are adapted to higher temperature climate and have spread to wheat producing areas of world that were perversely less affected by wheat stripe rust disease (Ali *et al*., 2014). In Ethiopia, the rapid emergence of virulent pathotypes of *Pst* 11, 16 and 17 have overcome most of recently released cultivars which are best resistant previous manner and known yellow rust resistant differential lines. Ethiopian institute of Agricultural research (EIAR) and Regional Research Institutes (RRI), for the last six decades more than 102 bread wheat varieties of local cross, CIMMYT and ICARDA origins including elite lines have been released with continuous improvement of best adapted in yield, acceptable end use qualities and disease resistance (Solomon *et al*., 2022). However, less than 20 varieties cover countries wheat growing areas and unfortunately these released mega cultivars are being susceptible to periodic outbreaks of yellow rust races without frequent fungicides application; farmers, seed enterprises and private wheat growers could not produce attainable quality and quantity of wheat yield.

In order reduce opportunity of rust pathogens that develops resistance to fungicides and yield losses, testing of best lines in dedicated rust nursery sites and releasing resistant wheat varieties are the most economical, sustainable and effective way for the management of yellow rust mainly for wheat producers in the developing countries. Thus, taking in to consideration, and to alleviate the continuous outbreaks of new yellow rust races; routine work needs in adequate monitoring and searching of novel durable sources of resistant wheat genotypes against yellow rust disease. So the objective of the study was to examine novel sources of durable resistant wheat genotypes tested in dedicated yellow rust disease nurseries.

MATERIALS AND METHODS OF RESEARCH

The trial was implemented at Kulumsa Agricultural Research Center sub-stations of Bekoji which located at 7º 32' 27'' North (N), 39º, 15', 21'' East (E) with altitude range of 2780 meters and Meraro 7º 24' 27'' North, 39º, 14', 56'' East (E) with altitude range of 2990 meters above sea level. Monthly maximum and minimum temperature of the Meraro and Bekoji experimental sites have received 5.7 and 18.1℃, and 7.9 and 18.6℃, and with annual rainfall of 1196 and 102 millimeters respectively. Both locations represent best screening and hotspot areas to yellow rust and characterized in receiving extended rainfall and bimodal cropping systems for major wheat production potential agro ecologies.

A total of 1166 genotypes which were CIMMYT and ICARDA sources of introductions, and local cross, and commercial cultivars (checks) were examined for the durable resistance to yellow rust disease in dedicated hotspot sites. Those genotypes were tested the preliminary screening process of observation nurseries at Kulumsa Agricultural Research Center main stations of quarantine site and advanced lines of preliminary variety trials (PVT), national variety trials (NVT) and variety verification trial (VVT) and suggested to test in severely affected hotspots and dedicated disease nursery sites of yellow (stripe) rust) in field condition.

The experiment was conducted with partially replicated row column design consisted of 2028 entries. The genotype spacing of each entry was planted length of 0.5 meter and row spacing of 0.2meter apart in single row in 26 blocks comprised 78 genotypes in each block.

Mixtures of highly susceptible different varieties namely Morocco, Kubsa, Digalu, PBW343, Ogolcho and Hidassie were planted parallel to the each block and perpendicular to each entry used as spreader (infector rows) to receive uniform inoculum to the entries. All other weed and agronomic management practices were implemented as per the recommendations of the disciplines.

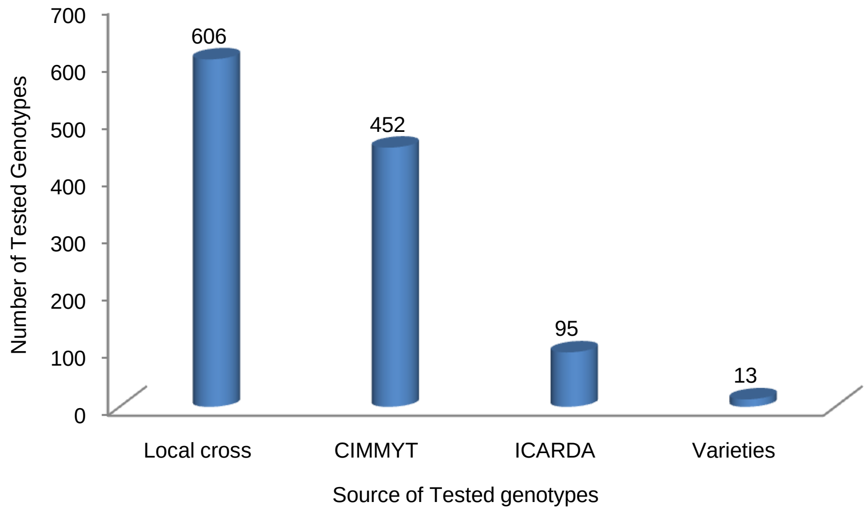

Figure 1 – Number of tested genotypes with source of introductions

Ultra violate (spray) inoculation was applied two times during early seedling and end of tillering stages whereas syringe (point) inoculation techniques was done at stem elongation stage for field inoculation of stripe rust isolates in both dedicated screening sites. In both methods the spores were collected in belg and early warning seasons of rust surveys from different fields of Arsi and West Arsi zones of mandated wheat belt areas. Pathogenicity test was done in Kulumsa Agricultural Research Center controlled condition of greenhouse due to sensitivity of disease symptoms environmental factors and the spores were mixed with mineral oil for uniform distribution and to facilitate penetration of the spores in to leaf. The solution was sprayed by aid of ultra-violate spray gun to wheat plants.

Yellow (stripe) rust disease scoring was done three times at both Bekoji and Meraro dedicated disease screening nursery sites at fourteen days interval, starting of susceptible spreader rows 20% disease severity by both modified cob (Peterson *et al*., 1948) and 0 to 9 scales using electronic data scoring tablet. Response of wheat genotypes were evaluated and scored through final rust severity and host plant response to infection according to Roelfs *et al*., (1992), and coefficient of infection (CI) was intended by multiplying the severity percentage and constant values given to each reaction type (Sarri *et a*l., 1974). The response values were given as; 0=immune, R (resistant) =0.2, resistant to moderately resistant (RMR) =0.3, MR (moderately resistant) =0.4, MRMS (moderately resistant to moderately suceptible-0.6, MS (moderately susceptible) =0.8, MSS (moderately susceptible to susceptible) =0.9, S (susceptible)=1.

RESULTS AND DISCUSSION

Of the 1166 tested genotypes 606, 452, 95 and 13 genotypes were sourced; local cross, CIMMYT and ICARDA introductions, and released varieties respectively. Different yellow rust response ranging from immune (0) to susceptible (S) field reactions were observed at both Bekoji and Meraro dedicated disease nursery sites. The final percentage yellow rust severity and response of genotypes were presented in figure 2. The percentage yellow rust severity indicated all cumulative results of the all resistant factors during the progress of disease epidemics and genotypes response (Parlevliet and Ommeren, A., 1975).

From the total of 1166 tested genotypes 5.8, 12.4, 4.6, 2.6, 71.2, 3.4% at Bekoji testing site showed moderately resistant (MR), moderately resistant to moderately susceptible (MRMS), moderately susceptible (MS), moderately susceptible to susceptible (MSS) and susceptible yellow rust disease reaction respectively while 0.5, 0.3, 11.7, 5.6, 3.9, 2.5, 70.2, 5.3% at Meraro testing site showed immune (0), Resistant (R), (moderately resistant (MR), moderately resistant to moderately susceptible (MRMS), moderately susceptible (MS), moderately susceptible to susceptible (MSS) and susceptible yellow rust disease reaction respectively (Figure 2).

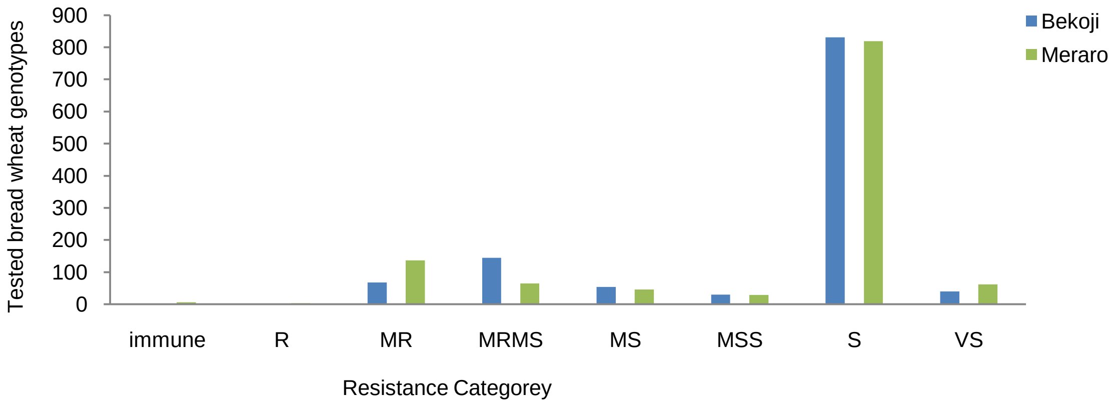

Figure 2 – Response of bread wheat genotypes to yellow (stripe) rust

In both Bekoji and Meraro testing locations 18% of tested genotypes were exhibited immune to Moderate yellow rust field reaction, but majority of genotypes with 76% showed susceptible and very susceptible field response in selection pressure that could not be recommended for the next breeding cycle and the remaining 16% exhibited moderately susceptible and moderately susceptible to susceptible genotype response (Table 1). In spite of high yellow rust epidemics at Bekoji and Meraro dedicated screening nursery sites 191 genotypes displayed low disease response exhibiting from 5 to 30 percent severity with compatible R, MR and MRMS disease response and are of prodigious significance to achieve current breeding program for durable resistance to yellow rust (Table 2). Wheat genotypes that could be susceptible at early seedling stage but revealed moderate type of reaction at adult plant stage of the dedicated rust screening sites might be with durable adult plant resistant genes to be simple and sound way to test for polygenic inheritance in utilizing genetic resistance (Singh *et al*., 2005). This strategy also agreed with work done by Zeng *et al* (2014) stated that resistant breeding through deployment of effective resistant genes for rust diseases over space and time in ordinarily used for parental lines and released varieties is an important strategy for utilizing genetic resistance to manage yellow rust in full potential.

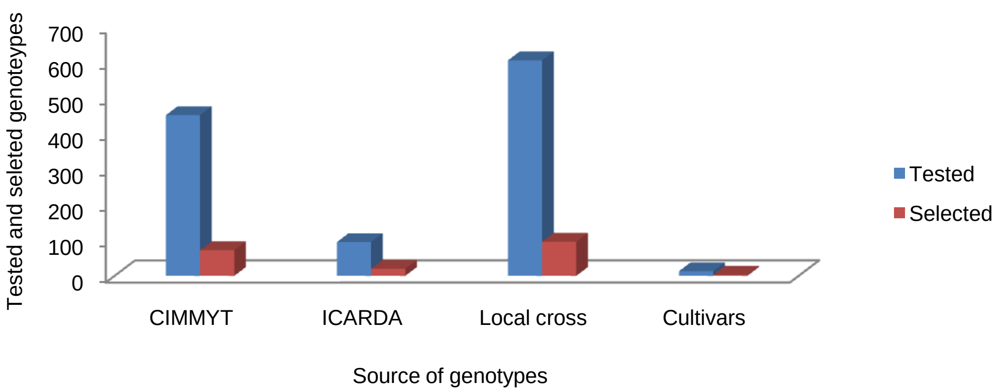

Figure 3 – Source of tested genotypes with selection pressure

From 606, 452, 95 and 13 tested genotypes 96, 72, 20 and 3 materials were performed best and selected for the resistance to yellow rust in dedicated screening nursery sites sourced from local cross, CIMMYT and ICARDA and commercial varieties respectively (Figure 3).

Of the candidate, released and currently cultivated 17 bread wheat varieties comprised with tested in dedicated screening nurseries at both sites, 75.5% of cultivars exhibited above 40 percent rust severities with susceptible and very susceptible varietal response to the currently prevalent yellow races (Table 3). Popularizing the newly released variety called kulumsa (EBW192346), facilitating the candidate (EBW192345) to release and using that good response to yellow rust resistance varieties and lines namely Kulumsa, Balcha and Dursa and EBW192345 could be recommended for crossing in national wheat improving center.

Table 1 – Summary of wheat genotypes in resistance and percent categories

Resistance Category	Bekoji		Meraro	
	No genotypes	Selection pressure (%)	No genotypes	Selection pressure (%)
immune - MRMS	212	18.2	210	18
MS – MSS	84	7.2	75	6.4
S –VS	870	74.6	881	75.6

Note: Immune=0, R= resistant, MR=moderately resistance, MRMS= moderately resistance to moderately susceptible.

Table 2 – Selected bread wheat genotypes for the resistance to both Yellow rust

Genotype	Bekoji			Meraro			Genotype	Bekoji			Meraro		
	YrSev	Rxn	CI	YrSev	rxn	CI		YrSev	Rxn	CI	YrSev	rxn	CI
EBW150181	10	MR	4	0	0	0	EBW170204	30	MRMS	18	10	MR	4
EBW160002	10	MR	4	0	0	0	EBW170209	20	MRMS	12	10	MR	4
EBW160036	5	MR	2	5	R	1	EBW170210	10	MRMS	6	10	MR	4
EBW160058	5	MR	2	5	R	1	EBW170211	10	MRMS	6	10	MR	4
EBW160063	10	MR	4	5	R	1	EBW170230	20	MRMS	12	5	MR	2
EBW160066	20	MR	8	20	MR	8	EBW170232	30	MRMS	18	10	MR	4
EBW160067	10	MR	4	5	MR	2	EBW170236	20	MRMS	8	10	MR	4
EBW160118	30	MR	12	10	MR	4	EBW170238	30	MRMS	18	10	MR	4
EBW170011	5	MR	2	10	MR	4	EBW170239	10	MRMS	6	20	MR	8
EBW170019	10	MR	4	10	MR	4	EBW170240	20	MRMS	12	10	MR	4
EBW170020	20	MR	8	10	MR	4	EBW170351	20	MRMS	12	30	MR	12
EBW170024	5	MR	2	10	MR	4	EBW170380	20	MRMS	12	10	MR	4
EBW170025	20	MR	8	20	MR	8	EBW170381	20	MRMS	12	5	MR	2
EBW170049	10	MR	4	10	MR	4	EBW170383	20	MRMS	8	10	MR	4
EBW170052	10	MR	4	10	MR	4	EBW170384	20	MRMS	12	20	MR	8
EBW170057	10	MR	4	10	MR	4	EBW170386	20	MRMS	8	10	MR	4
EBW170072	10	MR	4	5	MR	2	EBW170387	30	MRMS	18	5	MR	2
EBW170076	5	MR	2	10	MR	4	EBW170390	30	MRMS	18	10	MR	4
EBW170079	10	MR	4	5	MR	2	EBW170391	30	MRMS	18	10	MR	4
EBW170085	10	MR	4	10	MR	4	EBW170392	20	MRMS	12	10	MR	4
EBW170172	5	MR	2	5	MR	2	EBW170393	20	MRMS	12	5	MR	2
EBW170177	10	MR	4	10	MR	4	EBW170398	20	MRMS	12	20	MR	8
EBW170178	10	MR	4	10	MR	4	EBW170400	20	MRMS	12	10	MR	4
EBW170179	20	MR	8	10	MR	4	EBW170402	20	MRMS	12	10	MR	4
EBW170190	10	MR	4	10	MR	4	EBW170404	30	MRMS	18	10	MR	4
EBW170193	5	MR	2	10	MR	4	EBW170425	10	MRMS	6	5	MR	2
EBW170233	10	MR	4	10	MR	4	EBW182767	30	MRMS	18	10	MR	4
EBW170237	10	MR	4	20	MR	8	EBW190191	20	MRMS	12	10	MR	4
EBW170263	5	MR	2	10	MR	4	EBW192154	30	MRMS	18	5	MR	2
EBW170350	10	MR	4	20	MR	8	EBW192255	10	MRMS	6	10	MR	4
EBW170352	10	MR	4	5	MR	2	EBW192346	30	MRMS	18	5	MR	2
EBW170385	5	MR	2	5	MR	2	EBW192470	20	MRMS	12	10	MR	4
EBW190196	10	MR	4	10	MR	4	EBW192493	20	MRMS	12	10	MR	4
EBW192345	10	MR	4	10	MR	4	EBW192800	20	MRMS	12	10	MR	4
EBW202020	20	MR	8	10	MR	4	EBW193173	20	MRMS	12	5	MR	2
EBW202053	10	MR	4	5	MR	2	EBW202087	30	MRMS	18	20	MR	8
EBW202054	10	MR	4	5	MR	2	EBW202211	20	MRMS	12	20	MR	8
EBW202055	10	MR	4	5	MR	2	EBW202267	20	MRMS	12	10	MR	4
EBW202056	10	MR	4	10	MR	4	EBW202276	20	MRMS	12	5	MR	2
EBW202128	10	MR	4	10	MR	4	EBW202363	20	MRMS	12	10	MR	4
EBW202207	10	MR	4	10	MR	4	EBW202475	20	MRMS	12	10	MR	4
EBW202239	10	MR	4	10	MR	4	EBW204020	20	MRMS	12	5	MR	2
EBW202406	10	MR	4	5	MR	2	EBW204044	20	MRMS	12	10	MR	4
EBW202434	20	MR	8	5	MR	2	EBW212099	20	MRMS	12	10	MR	4

Table 2 Continue

EBW202436	10	MR	4	5	MR	2	EBW212106	20	MRMS	12	10	MR	4
EBW202466	10	MR	4	5	MR	2	EBW212306	30	MRMS	18	10	MR	4
EBW202471	10	MR	4	10	MR	4	EBW212368	20	MRMS	12	10	MR	4
EBW202472	10	MR	4	5	MR	2	EBW212371	20	MRMS	12	10	MR	4
EBW202473	10	MR	4	10	MR	4	EBW212574	20	MRMS	12	10	MR	4
EBW204023	10	MR	4	5	MR	2	EBW212575	10	MRMS	6	30	MRMS	18
EBW212116	10	MR	4	10	MR	4	EBW212577	20	MRMS	8	10	MRMS	6
EBW212354	10	MR	4	10	MR	4	EBW212845	10	MRMS	6	10	MRMS	6
EBW212705	10	MR	4	30	MRMS	18	EBW213073	30	MRMS	18	20	MRMS	8
EBW212778	10	MR	4	30	MRMS	18	EBW214005	20	MRMS	12	10	MRMS	6
EBW212779	10	MR	4	30	MRMS	18	EBW214009	10	MRMS	6	10	MRMS	6
EBW212848	20	MR	8	30	MRMS	18	EBW214011	20	MRMS	12	20	MRMS	12
EBW214017	10	MR	4	20	MRMS	12	EBW214012	20	MRMS	12	20	MRMS	12
EBW214029	10	MR	4	30	MRMS	18	EBW214045	30	MRMS	18	20	MRMS	12
EBW214031	10	MR	4	30	MRMS	18	EBW214061	20	MRMS	12	20	MRMS	12
EBW222161	20	MR	8	30	MRMS	12	EBW222059	20	MRMS	12	30	MRMS	18
EBW222919	10	MR	4	20	MRMS	12	EBW222088	30	MRMS	18	20	MRMS	12
EBW223021	10	MR	4	10	MRMS	6	EBW222089	20	MRMS	12	20	MRMS	12
EBW160017	20	MRMS	12	0	0	0	EBW222110	30	MRMS	18	30	MRMS	18
EBW160068	20	MRMS	12	10	MR	4	EBW222160	20	MRMS	12	30	MRMS	18
EBW160069	10	MRMS	6	10	MR	4	EBW222174	30	MRMS	18	20	MRMS	12
EBW160098	20	MRMS	12	10	MR	4	EBW222176	20	MRMS	12	20	MRMS	12
EBW170010	20	MRMS	12	10	MR	4	EBW222222	20	MRMS	12	20	MRMS	12
EBW170018	20	MRMS	8	20	MR	8	EBW222241	30	MRMS	18	20	MRMS	12
EBW170023	10	MRMS	6	10	MR	4	EBW222252	30	MRMS	18	10	MRMS	6
EBW170050	20	MRMS	12	5	MR	2	EBW222283	20	MRMS	12	10	MRMS	6
EBW170051	10	MRMS	6	10	MR	4	EBW222416	10	MRMS	6	20	MRMS	12
EBW170053	10	MRMS	6	10	MR	4	EBW222448	30	MRMS	18	30	MRMS	18
EBW170056	10	MRMS	6	5	MR	2	EBW222486	10	MRMS	6	30	MRMS	18
EBW170059	20	MRMS	12	10	MR	4	EBW222569	30	MRMS	18	10	MRMS	6
EBW170062	20	MRMS	12	5	MR	2	EBW222573	10	MRMS	6	30	MRMS	18
EBW170074	20	MRMS	12	20	MR	8	EBW222574	30	MRMS	18	20	MRMS	12
EBW170075	20	MRMS	8	10	MR	4	EBW222680	20	MRMS	12	30	MRMS	18
EBW170078	10	MRMS	6	10	MR	4	EBW222681	20	MRMS	12	10	MRMS	6
EBW170083	30	MRMS	18	5	MR	2	EBW222790	20	MRMS	12	10	MRMS	6
EBW170084	20	MRMS	8	10	MR	4	EBW222792	30	MRMS	18	20	MRMS	12
EBW170116	10	MRMS	6	20	MR	8	EBW222857	10	MRMS	4	20	MRMS	12
EBW170117	20	MRMS	12	10	MR	4	EBW222894	20	MRMS	12	20	MRMS	12
EBW170119	20	MRMS	12	10	MR	4	EBW222923	30	MRMS	18	10	MRMS	6
EBW170120	20	MRMS	8	20	MR	8	EBW222944	30	MRMS	18	30	MRMS	18
EBW170134	20	MRMS	12	10	MR	4	EBW223001	20	MRMS	12	30	MRMS	18
EBW170135	30	MRMS	18	10	MR	4	EBW223022	30	MRMS	18	20	MRMS	12
EBW170175	20	MRMS	12	10	MR	4	EBW224021	30	MRMS	18	30	MRMS	18
EBW170188	10	MRMS	6	10	MR	4	EBW224096	20	MRMS	12	10	MRMS	6
EBW170189	10	MRMS	6	10	MR	4	EBW224131	20	MRMS	12	30	MRMS	18
EBW170191	20	MRMS	12	15	MR	6	EBW224250	30	MRMS	18	30	MRMS	18
EBW170192	20	MRMS	12	20	MR	8	EBW224252	20	MRMS	12	20	MRMS	12
EBW170194	10	MRMS	6	10	MR	4	EBW224253	30	MRMS	18	20	MRMS	12
EBW170195	20	MRMS	12	10	MR	4	EBW224257	10	MRMS	6	10	MRMS	6
EBW170196	10	MRMS	6	10	MR	4	EBW224258	20	MRMS	12	20	MRMS	12
EBW170197	30	MRMS	18	20	MR	8							

Note: YrSev=yellow rust percentage severity, rxn=varietal response, CI= coefficient of infection value of the genotype.

Table 3 – Response of currently cultivated commercial bread wheat varieties to yellow rust

Varieties	Meraro	Bekoji
Balcha	20MR	20MR
Dursa	30MRMS	10MRMS
Daka	40MSS	30MSS
Shaki	50S	40S
Danda'a	50S	50S
Lemmu	40S	50S
Boru	70S	60S
Alidoro	70S	50S
Abay	70S	70S
Hidassie	70S	60S
Kakaba	70S	60S
Kingbird	70S	60S
Morocco	90S	90S
EBW192345 (Candidate)	5MR	20MRMS
EBW192346 (recently released)	10MR	10MRMS

Note: MR=moderately resistance, MRMS= moderately resistance to moderately susceptible, MSS= moderately susceptible to susceptible, S=susceptible.

CONCLUSION

Resistant wheat genotypes to yellow rust disease facilitates the wheat improving and breeding programs to examine broadly adapted genotypes that compromises steady performance across a wide range of testing sites as well as under specific conditions with high disease epidemics of wheat production areas. It is decided that from the existing study the durable rust resistant genotypes identified from this research with better level of adult plant resistance to be exploited in wheat improving program of Ethiopia. Therefore, the selected genotypes could be verified the yield related parameters across the national level and included in multipurpose crossing blocks in order to advance weakness of the previously released varieties. Besides, genotyping of marker assisted selection is required to approve what resistant genes are carried in adult (durable) plant resistant genotypes thus, may play an important role to develop resistant wheat varieties in Ethiopia.

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