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Association Between Dominant Wheat Stem Rust Races Found in Ethiopia and Grain Yield in Advance Bread Wheat Genotypes

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ABSTRACT

The study was conducted in 2019 and in 2020 across two locations: Dhera and Asasa in Ethiopia to study the correlation between dominant stem rust races found in Ethiopia and grain yield on bread wheat genotypes found in the national wheat research program pipelines. Twenty three bread wheat genotypes and two released bread wheat varieties set as a Bread Wheat National Variety Trial by the national wheat research program for low altitude and planted at Dhera and Asasa. A square lattice design with two replications used for experiment conducted on the field. A plot of six rows, size of 2.5 m by 1.2 m, and a total area of 3 m^2 used. The same genotypes planted using complete randomized design in three replications at Kulumsa Agricultural Research Center green house. Seven-day old seedlings were inoculated with spores of selected races: TTTTF, TKTTF, TKKTF, TTRTF and BULK. Data on infection types (IT) were recorded 14 days after inoculation using 0–4 scale. Result in the study revealed that Grain yield had positive genotypic association with all four races but bulk at Dhera. A very high negative significant genotypic correlation r=-0.708*** obtained between Grain yield and field Stem rust diseases score at Asasa. Those genotypes carrying race-specific effective gens for the races used in the green house were resistance at the seedling stage. But, on the field, at the adult stage, they lost the resistance and become susceptible.

KEYWORDS: APR, genotypes, IT, races, stem, rust, wheat yellow rust

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1. INTRODUCTION

In Ethiopia, wheat productivity and production trend show increments for the past two decays (Adugnaw and Dagninet, 2020) . The country brought more land from low lands for wheat production under irrigation in targeting wheat self-sufficient (Further Africa, 2022). About 1.8 mha of land was covered with wheat in 2022, with a total expected production of 5.7 Mt (Abu, 2022) under rain-fed conditions. In addition about 1 mha of land was covered with wheat under irrigation to produce additional in the 2023.Due to this, wheat becomes economically one the most important crop in the country (Regasa, 2019).

But, wheat production in the Ethiopia threatened by Diseases (mainly rusts), pests (aphids, Green bug, shoot fly, and birds), and environmental factors (Acidity, low fertility, moisture stress etc.) (Mulu et al., 2022). Among the biotic factors, the three wheat rusts: stem, yellow, and leaf rusts are the major production constraints. Stem rust, caused by the fungus *Puccinia graminis* f. sp. tritici (Pgt), causes total crop loss during the epidemic years (Admassu et al.,2012; Denbel et al., 2013; Alemu et al., 2019; Delesa et al., 2022; Wuletaw et al., 2022).

The crop faces wheat rust pressure at different growth stage on the field. The extent of the damage depends on the stage at the time of infection and the severity of the rust (Figueroa et al., 2019). In Ethiopia, most of the time yellow rust, occurred early at seedling stage and, in epidemic year, devastates the crop seriously (Mayer et al., 2021). On the other hand, stem rust occurs mainly at late stage of the growth and, in epidemic years able to destroy the whole crop.

Mono cropping of wheat in potential wheat producing areas, favorable environmental condition for the development of the pathogen, and the nearby presence of alternate host are among the factors for rapid evaluation and wider virulence spectrum of wheat stem rust pathogen in Ethiopia (Netsan et et al., 2018; Belayneh and Emebet, 2005; Admassu et al., 2009;Getaneh et al., 2016; Hailu et al., 2015). Because of more frequent race shifting, the resistance gene in money widely adopted bread wheat varieties break down by stem rust disease and become highly susceptible (Beyene, 2018).

Wheat rust resistance genes have non- exclusively two groups: race-specific and race-non-specific genes. Race-specific genes are effective and carry high resistance levels for the designated races, but they last for a short period because of the high frequency of race evolution. Particularly in a place where high disease pressure and favorable environmental conditions exist occurrence of virulent races and the frequency of broken gens are very high (Huerta et al., 2020; Huerta et al., 2011; Wellings et al., 2011; Mapuranga et al., 2022; Dinglasan et al., 2022; Zhang et al., 2014); In contrast, rare non-specific gens delivered from minor to moderate resistance. The plant carrying these genes is susceptible at the seedling stage but later resistant at the adult plant stage. It is called slow rusting or sometimes referred to as adult plant resistance gene APR. A combination of race-specific genes and race-non-specific miner genes through gene pyramiding allows the development and release of near-to-immune, durable resistance bread wheat varieties for wheat-growing farmers (Singh et al., 2008; Muhammad et al., 2017). The objective of this study was to observe the correlation between dominant stem rust races found in Ethiopia and grain yield on bread wheat genotypes found in the national wheat research program pipelines.

2. MATERIALS AND METHODS

2.1. Description of the test site for field experiment, year of the study, study material and design

The study was conducted in 2019 and in 2020 across two locations: Dhera and Asasa. Dhera uses to test trials for low-land agro-ecologies or moisture-stress areas; It is between 080 19'06.3''N latitudes 0390 19' 0.74'' E longitude at the altitude of 1677 m a.s.l; Annual rainfall is 680 mm with 27.80°C and 140°C maximum and minimum temperatures. Asasa uses to evaluate trials set for the terminal moisture stress areas and optimum areas; It is between 07°07'228"N latitude and 39°11'932"E longitude at an altitude of 1360; it received an annual rainfall of about 620 mm with a minimum and maximum temperature of 5.8°C and 23.6°C respectively. Twenty-three bread wheat genotypes and two released bread wheat varieties were evaluated as a Bread Wheat National Variety Trial (BWNVT) by the national wheat research program for low altitude. The program introduced some of the genotypes from CIMMYT and ICARDA. Then evaluated, selected, and advanced for a few years across different locations. Few genotypes were from the national crosses.

The field experiment carried out in a square lattice design with two replications at Dhera and Asasa. The plot was of six rows, a size of 2.5 m by 1.2 m, and a total area of 3 m^2 used for the trial. The space between rows, blocks, and reps was 20 cm, 1 m, and 1.5 m consecutively. Urea and NPS fertilizers added as per recommendation for the areas at the planting and top dressing at seedling stage.

2.2. Evaluation of seedling stage for dominant stem rust races in green house

Sample of the stem rust spores collected from major wheat-producing areas of Ethiopia, where high stem rust race diversity is expected to be high, and then transported to Ambo plant protection lab for race identification. A universally susceptible wheat variety (McNair) (Roelfs, 1992; Fetch and Dunsmore, 2004), the Single pustule isolates isolated and multiplied to inoculate the differentials.

The single pustule isolate that multiplied on universal susceptible variety inoculated to differentials. The differentials were originally brought to Ambo plant protection from Cereal Disease Laboratory (CDL), Minnesota, USA, by the Ambo plant protection lab. These differentials are known for being major effective genes for different stem rust races. The races: TTTTF, TKTTF, TKKTF, and TTRTF were identfied in the Ambo plant protection lab following standard race identification protocol. The known races were brought to Kulumsa Agricultural Research Center from the Ambo plant protection lab for evaluation of advanced bread wheat genotypes in greenhouse.

Twenty-three advanced bread wheat genotypes and two checks: Daka, a recently released resistance bread wheat variety for stem rust, and Ogolcho, an obsolete susceptible bread wheat variety, were planted using a complete randomized design in three replications at Kulumsa Agricultural Research Center greenhouse. Five seeds from each genotype planted in medium size of plastic pots separately. Seven-day-old seedlings (the first leaf fully expanded, and the second leaf is just emerged to grow) inoculated with spores of selected races: TTTTF, TKTTF, TKKTF, TTRTF, and BULK. For incubation, inoculated plants moistened with fine droplets of distilled water using an atomizer. After 30 min, seedlings were placed in a dew chamber for 18 hrs dark period at 18–22°C and 98–100% relative humidity (RH) followed by exposure to light at least for 3–4 h to provide a favorable condition for stem rust infection. Seedlings were then allowed to dry their dew for about 1–2 h. Following this, the seedlings transferred from the dew chamber to glass compartments in the greenhouse, where conditions regulated at 12 h photoperiod and a temperature range of 18–25°C and RH of 60–70%. Data on infection types (IT) recorded 14 days after inoculation using a 0–4 scale, Its "0","1", and 2 were considered as resistant, whereas Its "3" and "4" were considered as susceptible (Stakman et al., 1962). Then, the infection type (IT) score converted to a 0–9 linear diseases scale to do the association analysis according to (Zhang et al., 2014): Simple infection types were converted as follows: 0, 1-, 1, 1+, 2-, 2, 2+, 3-, 3 and 3+ were coded as 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9, consecutively. IT 4 was converted to 9.

2.3. Data analysis

All data in the study computed using R-software version 3.6.0 (R core team, 2018)

Genotypic and phenotypic correlations between grain yield and wheat stem rust dominant races found in Ethiopia to see the association using a method suggested by (Singh and Chaudhary, 1985; Fehr et al., 1993).

rg=(gcovx-y)/(d√δ²gxδ²gy) ....(1)

rp=....................(2)

Where, rg and rp are genotypic and phenotypic correlation coefficients, respectively; g cov x·y and pcovx · y are genotypic and phenotypic covariance's between variables x and y, respectively; δ2gx and δ2px are genotypic and phenotypic variances, respectively, for variable x; and δ2gy and δ2py are genotypic and phenotypic variances, respectively, for variable y.

3. RESULTS AND DISCUSSION

CGIAR centers like CIMMYT and ICARDA Interrogated Many effective genes, race-specific or major gen and non-race-specific or minor genes for wheat stem rust diseases in wheat germplasm through their crossing programs. The Ethiopian National Wheat Research Program introduces germplasms from these centers and puts them in breeding program pipelines together with germplasms from its crossing programs. These genes are race specific and effective for dominant races isolated and identified so far in the country, including races: TKTTF, TKKTF, TTRTF, and TTTTF. TKTTF and TKKTF are the wildly distributed races that account for about 85% of the frequency of dominant races found in Ethiopia (Endale et al., 2015; Kitessa et al., 2021). The scores of the genotypes against the dominant races taken at the seedling stage in the greenhouse, Whereas the Yield and stem rust taken from the field. The whole performance of the genotypes against these races showed resistance, moderately resistant and susceptible types (Table 3).

Grain yield had a positive genotypic association with all four races but bulk at Dhera. Although not significantly correlated, bulk race and grain yield had a negative correlation r=-0.168(Table 1). High positive significant correlation r=0.999*** obtained between race TTTTF and grain yield (table 1); it is due to those susceptible genotypes for this race in the greenhouse delivering high yield on the field. These genotypes have adult plant resistance genes. Grain yield and stem rust score showed a non-significant negative correlation r=-0.282 (Table 1).

A negative significant genotypic correlation r=-0.463* was found between stem rust score and Hectoliter weight (HWT), and a non-significant negative genotypic correlation r=-0.129 between stem rust and thousand kernel weight (TKW) (Table 1). Likewise, a negative significant phenotypic correlation r=-0.444* was found between stem rust score and hectoliter weight (HLW), and a non-significant negative phenotypic correlation r= -0.076 between stem rust score and thousand kernel weight at Dhera (Table 1). Stem rust score had a negative phenotypic correlation r=-0-271 with Thousand Kernel weight (TKW)

Table 1: Genotypic correlation below the diagonal and phenotypic correlation above the diagonal among tested variables for twenty five bread wheat genotypes planted at Dhera

Traits	DTH	DTM	PHT	SR	TKW	HLW	GYLD	TKTTF	TKKTF	TTRTF	TTTTF	BULK
DTH		0.59	0.548**	0.256	-0.370	-0.674***	0.401*	0.172	0.030	0.167	-0.140	0.063
DTM	0.303		0.068	0.211	-0.048	-0.389	0.003	0.126	0.023	0.070	0.263	-0.088
PHT	0.871***	0.093		0.423*	-0.011	-0.337	0.688***	0.339	0.201	0.286	0.174	0.288
SR	0.324	0.235	0.598**		-0.076	-0.444*	-0.035	0.231	0.243	-0.051	-0.295	0.234
TKW	-0.432*	-0.070	-0.306	-0.129		0.557**	-0.032	0.029	0.003	0.181	0.354	0.065
HLW	-0.806***	-0.500*	-0.751***	-0.463*	0.486*		-0.097	-0.185	-0.011	0.100	0.436*	-0.160
GYLD	0.658***	-0.043	0.708***	-0.282	-0.490*	-0.407*		0.136	0.053	0.261	0.297	0.080
TKTTF	0.545**	-0.112	0.509**	0.599**	0.040	-0.488*	0.341		0.478*	0.634***	0.119	0.697***
TKKTF	-0.008	-0.020	0.252	0.412*	0.004	-0.108	0.147	0.391		0.466*	0.010	0.490*
TTRTF	0.270	0.086	0.340	-0.203	0.220	-0.058	0.434*	0.738***	0.560**		0.205	0.349
TTTTF	-0.254	0.073	-0.146	-0.734***	0.707***	0.999***	0.999***	-0,999***	-0,999***	-0.111		-0.028
BULK	0.099	-0.116	0.299	0.272	0.053	-0.022	-0.168	0.999***	0.698***	0.427*	-0.042	

DTH: Date of heading; DTM: Date of maturity;SR: Stem rust score on field;TKW: Thousand kernel weight; HLW: Hectoliter weight; GYLD: Grain yield; TKTTF, TKKTF, TTRTF, TTTTF: Dominant stem rust races found in Ethiopia; Bulk: The bulk of the four races

and a very high negative significant correlation r=-0.278*** with Hectoliter weight (HLW) at Asasa (Table 2). The rust causes the seed to shrivel and prematurely ripen, which affects thousand kernel weights and hectoliter weight. Genotypes with better resistance, adult plant resistance (APR) on the field have good quality seed or grain with higher Thousand Kernel Weight (TKW) and Hectoliter Weight (HLW) (Tegwe et al.,2018;Msundi et al., 2021).

On the other location, Asasa genotypic correlation was positive and non-significant between grain yield and all races except TKKTF r=-0.093 (table 3), Which is a Digelu race, the second most abundant after Ug99, the TTKSK race in the country (Endale et al., 2015); Also the genotypic correlation between race TTTTF and grain yield was a very high positive significant correlation r=0.903*** at Asasa; Positive significant correlation is because of highly

Table 2: Genotypic correlation below the diagonal and phenotypic correlation above the diagonal among tested variables for twenty five bread wheat genotypes planted at Assasa

Traits	DTH	DTM	PHT	SR	TKW	HLW	GYLD	TKTTF	TKKTF	TTRTF	TTTTF	BULK
DTH		0.125	0.277	0.210	-0.444*	-0.311	-0.258	-0.015	-0.026	0.214	0.153	-0.276
DTM	0.184		0.136	0.318	0.141	-0.164	-0.420	-0.004	0.090	0.176	0.285	-0.123
PHT	0.368	0.175		0.481*	0.100	-0.243	0.049	0.487*	0.181	0.284	0.146	0.305
SR	0.144	0.367	0.605**		-0.271	-0.728***	-0.595***	0.155	0.268	-0.060	-0.102	0.135
TKW	-0.454*	0.118	0.060	-0.242		0.514**	0.447*	0.318	0.086	0.394	0.348	0.264
HLW	-0.359	-0.229	-0.275	-0.720	0.592**		0.788***	-0.146	-0.198	0,049	0.163	-0.051
GYLD	-0.115	-0.636***	0.135	-0.708***	0.484*	0.937***		0,123	-0.125	0.103	0.307	0.235
TKTTF	-0.468*	-0.482*	0.702***	0.046	0.863***	-0.121	0.264		0.478*	0.634***	0.119	0.697***
TKKTF	-0.316	-0.017	0.047	0.375	0.105	-0.150	-0.093	0.391		0.466*	0.010	0.490*
TTRTF	0.203	0.287	0.400*	-0.132	0.714***	0.241	0.184	0.738***	0.560**		0.205	0.349
TTTTF	0.999***	0.503*	-0.176	-0.509**	0,999***	0.640***	0.903***	-0.999***	-0.999***	-0.111		-0.028
BULK	-0.378	-0.166	0.381	0.169	0.333	-0.018	0.265	0.999***	0.698***	0.427*	-0.042	

DTH: Date of heading; DTM: Date of maturity;SR: Stem rust score on field;TKW: Thousand kernel weight;HLW: Hectoliter weight; GYLD: Grain yield; TKTTF, TKKTF, TTRTF, TTTTF: Dominant stem rust races found in Ethiopia; Bulk: The bulk of the four races

Table 3: Average scores of the four races, the bulk race, stem rust coefficient of infection scores at Dhera and Asasa, and grain yield of the genotypes at Dhera and Asasa

Entry	Genotype	TKT-TF	TKK-TF	TTR-TF	TTT-TF	BULK	DRS-CI	AAS-RCI	DRG-YLD	AAG-YLD	MGY-LD
1	DAKA	5.00	4.00	5.67	6.00	4.33	10.00	6	1.8	1.76	1.79
2	ETBW 9116	6.00	5.00	8.33	6.00	5.33	6.33	2	2.7	1.65	2.20
3	ETBW 9119	8.00	5.33	7.33	5.33	5.00	8.00	1	1.9	1.94	1.93
4	ETBW 9128	6.00	5.00	4.33	1.67	5.33	33.33	30	0.8	1.48	1.16
5	ETBW 9136	5.00	6.00	5.33	4.00	5.00	14.00	24	2.4	2.07	2.22
6	ETBW 9139	6.67	7.33	6.33	6.33	6.67	4.33	6	1.1	2.04	1.58
7	ETBW 9149	7.00	3.00	7.00	5.00	5.00	7.00	0.5	1.3	1.74	1.54
8	ETBW 9065	7.33	5.67	7.33	6.67	6.33	13.33	8	1.1	2.11	1.60
9	ETBW 9077	3.67	2.00	4.33	7.00	0.01	3.47	8	1.9	1.41	1.67
10	ETBW 9078	4.33	5.00	5.33	3.67	5.00	0.87	0.5	1.3	1.40	1.34
11	ETBW 9080	7.33	2.00	6.67	8.00	6.33	4.00	2	1.7	2.06	1.89
12	ETBW 9172	6.33	6.33	6.67	5.00	6.33	4.00	4	1.9	1.94	1.93
13	ETBW 9396	4.33	2.00	2.00	5.00	3.33	0.20	0.2	1.2	1.90	1.53
14	ETBW 9452	5.33	5.00	5.33	6.33	5.00	0.20	0.05	1.0	1.71	1.37
15	ETBW 9543	5.00	4.00	5.33	7.00	5.67	4.00	1	1.4	1.88	1.67
16	ETBW 9545	6.33	7.33	7.67	6.00	6.00	1.67	6	1.1	1.63	1.36
17	ETBW 9641	6.33	5.67	5.67	7.00	6.00	16.67	60	1.9	1.78	1.82
18	ETBW 9642	5.33	5.33	7.33	4.33	5.33	18.33	50	1.2	1.56	1.40
19	ETBW 9646	7.33	6.00	6.67	6.00	6.00	18.33	24	1.7	1.79	1.75
20	ETBW 9647	6.00	6.67	5.67	6.00	5.33	46.67	70	1.6	1.28	1.42
21	ETBW 9648	6.00	7.33	7.33	7.33	5.67	2.07	2	2.5	1.88	2.18
22	ETBW 9650	5.33	5.67	6.00	6.33	5.00	13.33	60	1.2	1.37	1.28
23	ETBW 9651	4.00	4.00	7.00	6.00	0.67	0.93	0.05	1.0	1.89	1.46
24	ETBW 9652	5.33	7.00	6.33	6.33	3.67	3.33	4	1.4	1.65	1.54
25	OGOLCHO	7.00	7.00	7.33	2.33	5.33	14.67	18	1.2	1.22	1.21

TKTTF, TKKTF, TTRTF, TTTTF: Dominant stem rust races found in Ethiopia; Bulk: The bulk of the four races; DRSRCI: Dhera stem rust coefficient of infection on field; AASRCI: Asasa stem rust coefficient of infection on field; DRGYLD: Dhera grain yield; AAGYLD: Asasa grain yield; MGYLD; ETBW+number: Ethiopian bread wheat; and the number is a unique accession number given for individual genotypes by the national wheat research program

susceptible genotypes for race TTTTF at the greenhouse probably had many accumulated minor genes through the crossing that make the genotypes develop adult plant resistance on the field.

Grain yield and stem rust score on the field had a negative genotypic correlation at Dhera and Asasa. Grain yield and stem rust score had a high negative significant genotypic correlation r=-0.708***. At Asasa (Table 2). Grain yield largely depends on the performance of the genotypes on the field. Hence, resistance genotypes for stem rust at Asasa delivered higher grain yield than the susceptible genotypes.

At Dhera, Grain yield and stem rust score had a non-significant negative correlation r=-0.282 (Table 1). However, susceptible genotypes gave lower grain yield compared to the resistance genotype. In high disease pressure, the genotypes were exposed to many new races that affect grain yield (Singh et al., 2006).

The phenotypic expression of the trait of the plant is a result of the genetic makeup of the plant and the environment in which it grows. It is the end product for which the crop is grown. Grain yield and the four dominant races: TKTTF, TKKTF, TTRTF, and TTTTF, had positive non-significant phenotypic correlations at Dhera. But a negative phenotypic correlation r=-0.035 was obtained between grain yield and responses to stem rust score recorded on the field (table 1). The correlation was not significant. However, the correlation was negative.

At Asasa, except between grain yield and Stem race TKKTF, a positive non-significant phenotypic correlation obtained. Stem rust TKKTF, Digelu race had A negative non-significant correlation r=-0.125 with grain yield. But the phenotypic correlation between stem rust score on the field and grain yield was negative and very significant r=-0.595*** (Table 2). Therefore, the resistance genotypes for wheat stem rust disease on the field have high yielder than the susceptible genotypes. Wheat stem rust disease can cause up to 100% yield on susceptible varieties under favorable season for the development of this disease (Hulluka et al., 1991; Ayele et al., 2002). Hence, it is one of the determinant factors in wheat grain yield.

Breeding programs work in areas disposed to this wheat rust more curious for resistance genotypes on their pipelines. On the field, the crop grows in the occurrence of the number of races in addition to those identified as dominant races. That is why the result in this study shows that the performance of the genotypes for the wheat stem rust disease in the greenhouse is different from that of the performance in the field.

From the two experimental sites used, stronger associations were observed at Asasa between grain yield and stem rust score taken on the field than at Dhera. Grain yield and stem rust scores had strongly associated genotypic and phenotypic correlations r=-0.708*** and r=-0.595*** at Asasa (table 2). Whereas, at Dhera, weak but negative correlations r=-0.282 and r=-0.035 were found for genotypic and phenotypic correlations between grain yield and stem rust score (Table 1).

ETBW9116, ETBW9119, ETBW9136, ETBW9172, and ETBW9648 had higher average grain yields across the two test locations (Table 3). Genotype ETBW 9136 showed low Infection type (IT) for races TKTTF, TTRTF, and TTTTF. And BULK. Furthermore, among the high-yielding genotypes listed above, ETBW9136 showed a higher score for the coefficient of infection for stem rust taken on the field at both locations (table 3). It is moderately resistant on the field and greenhouse for the mentioned races. Genotype ETBW9648 exhibited very high infection types 6, 7.33, 7.33, and 7.33 for races TKTTF, TKKTF, TTRTF, and TTTTF consecutively. It is highly susceptible for all races. But, it is highly resistant to stem rust on the field. The stem rust coefficient of infections (SRCI) was 2.07 at Dhera and 2.00 at asasa recorded for this genotype. The grain yield is 2.18 t ha^{-1}, which is very high comparatively. Hence, the genotype has non-race specific genes which confirm slow rusting or called adult plant resistance. Furthermore, genotypes: ETBW9116, ETBW9119, and ETBW9172 are highly susceptible for the dominant races at the seedling stage in the greenhouse and highly resistant on the field the stem rust across both locations (table 3). They delivered high yields. Entry number 13,genotype ETBW9396 is best entry for stem rust diseases both in green house and on the field with medium grain yield. Therefore, it is worthy to use this genotype for crossing with another best genotypes or widely adopted bread wheat varieties as a parent.

The least mean grain yield, 1.16 t ha^{-1} recorded on genotype ETBW9128 for tested locations. This genotype showed moderate to high resistance for the four dominant races used in the study; with lower Infections Type (IT) 1.67 for race TTTTF; 4.33 for race TTRTF; 5 for race TKKTF, and 6 for TKTTF in the greenhouse (table 3). In contrast, it is highly susceptible on the field across both locations. High scores were observed for stem rust coefficients of infection SRCI=33.33 at Dhera and SRCI= 30 at Asasa. Possibly, the genotype has no adult plant resistance to stem rust.

4. CONCLUSION

Genotypes carried race-specific effective genes for the races used in the greenhouse were resistant at the seedling stage, but, On the field, they lost the resistance and became susceptible. The others, which had gens with minor to moderate resistance to the stem rust, showed slow rusting on the field.

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6. REFERENCES

Abebe, D., Gadisa, A., Negash, G., Alemu, D., Habtemariyam, Z., Tafesse, S., Rut, D., Dawit, A., Zerihun, T., Bayisa, A., Abebe, G., 2022. Stability and performance evaluation of advanced bread wheat (*Triticum aestivum* L.) genotypes in optimum areas of Ethiopia. International Journal of Bio-resource and Stress Management 13(1), 69–80. HTTPS://DOI.ORG/10.23910/1.2022.2732.

Abu, T., 2022. Grain and feed annual. report number: ET2022-0014. Retrieved on 22 May 2023 from https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Grain%20 and%20Feed%20Annual_Addis%20Ababa_Ethiopia_ET2022-0014.pdf

Admassu, B., Friedt, W., Ordon, F., 2012. Stem rust seedling resistance genes in Ethiopian wheat cultivars and breeding lines. African Crop Science Journal 20, 149–162

Admassu, B., Lind, V., Friedt, W., Ordon, F., 2009. Virulence analysis of *Puccinia graminis* f. sp. tritici populations in Ethiopia with special consideration of Ug99. Plant pathology 58, 362–69.

Adugnaw, A., Dagninet, A., 2020. Wheat production and marketing in Ethiopia: Review study, Cogent Food & Agriculture, 6, 1, 1778893, DOI: 10.1080/23311932.2020.1778893

Alemu, A., Getnet, M., 2019. Yield loss assessment in bread wheat varieties caused by yellow rust (*Puccinia striiformis* f. sp. *tritici*) in Arsi highlands of South Eastern Ethiopia. American Journal of BioScience 7(6), 104-112. doi: 10.11648/j.ajbio.20190706.14

Ayele, B.H., 2002. Breeding bread wheat with multiple disease resistance and high yield for the Ethiopian highlands: broadening the genetic basis of yellow rust and tan spot resistance. 2002, Gottingen University, Germany: Germany.

Belayneh, A., Emebet, F., 2005. Physiological races and virulence diversity of *Puccinia graminis* f. sp. tritici on wheat in Ethiopia. Phytopathologia Mediterranea 44, 313–318

Beyene, B.E., 2018. Status and challenges of wheat stem rust (*Puccinia Graminis* F.Sp. Tritici) and threats of new races in Ethiopia. International Journal of Forestry and Horticulture (IJFH). Vol 4, Issue 4, 2018, PP 22-31DOI: http://dx.doi.org/10.20431/2454-9487.0404003 .

Denbel, W., Badebo, A., Alemu, T., 2013. Evaluation of Ethiopian commercial wheat cultivars for resistance to stem rust of wheat race UG99. International Journal of Agronomy and Plant Production 4, 15–24

Dinglasan, E., Periyannan, S., Hickey, L.T., 2022. Harnessing adult-plant resistance genes to deploy durable disease resistance in crops. Essays Biochem 66(5), 571–580. doi: 10.1042/EBC20210096. PMID: 35912968; PMCID: PMC9528086.

Endale, H., Getaneh, W., Worku, D., Wubishet, A., Tekelay, A., Agengehu, M., 2015. Distribution of stem rust (*Puccinia graminis* f. sp. tritici) races in Ethiopia. Plant 3(2), 15-19. doi: 10.11648/j.plant.20150302.11

Fehr, W.R., 1993. Principles of cultivar development. Vol. 1.Theory and technique. Macmillan Publishing Co., USA

Fetch Jr, T.G., Dunsmore, K.M., 2004. Physiologic specialization of *Puccinia graminis* on wheat, barley, and oat in Canada in 2001. Candian Journal of Plant Pathology 26(2), 148–155.

Figueroa, M., Hammond-Kosack, K.E., Solomon, P.S., 2018. A review of wheat diseases-a field perspective. Mol Plant Pathol 19(6), 1523–1536. doi: 10.1111/mpp.12618. Epub 2017 Dec 26. PMID: 29045052; PMCID: PMC6638159.

Further Africa, 2022. Ethiopia wheat farm irrigation. Retrieved on 17. Augest, 2023 from https://furtherafrica.com/2022/01/04/ethiopia-expands-wheat-farms-irrigation/

Getaneh, G., Endale, H., Teklu, N., 2016. Detection of barberry plants (*Berberis holstii*) as an alternate host of stem rust (*Puccinia graminis*) of wheat in Ethiopia. Pest Management Journal of Ethiopia 19, 17–26

Hailu, E., Woldeab, G., Denbel, W., Alemu, W., Abebe, A., Mekonnen, A., 2015. Distribution of stem rust (*Puccinia graminis* f. sp. *tritici*) races in Ethiopia. Plant 3, 15–19.

Huerta-Espino, J., Singh, R., Crespo-Herrera, L.A., Villaseñor-Mir, H.E., Rodriguez-Garcia, M.F., Dreisigacker, S., Barcenas-Santana, D., Lagudah, E., 2020. Adult plant slow rusting genes confer high levels of resistance to rusts in bread wheat cultivars from Mexico. Frontiers in Plant Science 11, 824. doi: 10.3389/fpls.2020.00824

Huerta-Espino, J., Singh, R.P., Germán, S., 2011. Global status of wheat leaf rust caused by *Puccinia triticina*. Euphytica 179, 143–160. https://doi.org/10.1007/s10681-011-0361-x.

Kitessa, G., Adugna, G., Bacha, N., 2021. Distribution and physiological races of wheat stem rust (*Puccinia graminis* F. Sp tritici) in north and east Shoa zones of Ethiopia. Journal of Plant Pathology & Microbiology 12, 557.

Mapuranga, J., Zhang, N., Zhang, L., Liu, W., Chang, J., Yang, W., 2022. Harnessing genetic resistance to rusts in wheat and integrated rust management methods to develop more durable resistant cultivars. Frontiers in Plant Science 13, 951095. doi: 10.3389/fpls.2022.951095. PMID: 36311120; PMCID: PMC9614308.

Hulluka, M., Woldeab, G., Andnew, Y., Desta, R., Badebo, A., 1991. Wheat pathology research in Ethiopia. Wheat Research in Ethiopia a Historical Perspective, 173–217. https://eurekamag.com/research/002/277/002277785.php

Meyer, M., Bacha, N., Tesfaye, T., Alemayehu, Y., Abera, E., Hundie, B., Woldeab, G., Girma, B., Gemechu, A., Negash, T., Mideksa, T., Smith, J., Jaleta, M., Hodson, D., Gilligan, C.A., 2021. Wheat rust epidemics damage Ethiopian wheat production: A decade of field disease surveillance reveals national-scale trends in past outbreaks. PLoS ONE,16(2). https://doi.org/10.1371/journal.pone.0245697

Muhammad, H., Muhammad, A.K., Yasir, A., Muhammad, M.J., Babar, I., Muhammad, N., Waseem, S., Faqir, M., 2017. Wheat breeding for durable rust resistance and high yield potential in historical prospective and current status. Advances in Zoology and Botany 5(4), 55–63, 2017. DOI: 10.13189/azb.2017.050404

Mulu, N., Hussein, S., IsacK, M., Seltene, A., 2022. Wheat production in the highlands of Eastern Ethiopia: opportunities, challenges and coping strategies of rust diseases, Acta Agriculturae Scandinavica, Section B-Soil & Plant Science, 72, 1, 563–575, DOI: 10.1080/09064710.2021.2022186

Msundi, E.A., Owuoche, J.O., Oyoo, M.E., 2021. Identification of bread wheat genotypes with superior grain yield and agronomic traits through evaluation under rust epiphytotic conditions in Kenya. Scientific Reports 11, 21415. https://doi.org/10.1038/s41598-021-00785-7.

Netsanet, B., Tsegaab, T., Getaneh, W., Endale, H., Bekele, H., Daniel, K., Fikirte, Y., Fufa, A., Wubishet, A., Teklay, A., Miruts, L., Alemar, S., Tesfaye, G., 2018. Distribution and frequency of wheat stem rust races (*Puccinia graminis* f. sp.tritici) in Ethiopia. Journal of Agricultural and Crop Research 6(5), 88–96

R Core Team, 2018. R: A language and environment for statistical computing. R Foundation for statsical Computing, Vienna, Austria. URL http://www.r-project.org/ .

Regasa, D., 2019. Wheat production, marketing and consumption in Ethiopia. Journal of Marketing and Consumer Research, 55. DOI: 10.7176/JMCR

Roelfs, A.P., 1992. Rust diseases of wheat: concepts and methods of disease management. Cimmyt, 1992

Singh, R.K., Chaudhary, B.D., 1985. Biometrical methodsin quantitative genetic analysis. Kalyani Publishers, N. Delhi, India

Singh, R.P., Hodson, D.P., Huerta-Espino, J., Jin, Y., Njau, P., Wanyera, R., Herrera-Foessel, S.A., Ward, R.W., 2008. Will stem rust destroy the world's wheat crop? Advances in Agronomy 98, 271–309

Singh, R.P., Rajaram, S., 2006. Breeding for disease resistance in wheat. http://www.fao.org/DOCREP/006/Y4011E/y4011e0b.htm. (Accessed on 12 June 2016)

Stakman, E.C., Stewart, D.M., Loegering, W.Q., 1962. Identification of physiologic races of *Puccinia graminis* var. tritici. U.S, Agricultural Research Service, ARS E617, 1–53.

Tadesse, W., Zegeye, H., Debele, T., Kassa, D., Shiferaw, W., Solomon, T., 2022. Wheat production and breeding in Ethiopia:Retrospect and Prospects. Crop Breeding, Genetics Genomics 4(3), e220003. https://doi.org/10.20900/cbgg20220003

Tegwe, S., Cornelia, M.B., Renee, P., Zacharias, A.P., 2018. Yield loss associated with differenet levels of stem rust resistance in bread wheat. Plant Disease 102(12).

Wellings, C.R., 2011. Global status of stripe rust: a review of historical and current threats. Euphytica 179, 129–141. https://doi.org/10.1007/s10681-011-0360-y

Zhang, D., Bowden, R.L., Yu, J., Carver, B.F., Bai, G., 2014. Association analysis of stem rust resistance in U.S. winter wheat. PLoS ONE 9(7), e103747. doi:10.1371/journal.pone.0103747.