Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2023, 13(2), 58-63, doi: 10.15421/2023_431

ORIGINAL ARTICLE

Evaluation of Ethiopian key location disease nursery for the novel sources of resistance to stem rust (*Puccinia graminis* f. s. *tritici*)

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Received: *16 March, 2023; Manuscript No: UJE-23-91935;* ***Editor assigned:*** *18 March, 2023, PreQC No: P-91935;* ***Reviewed:*** *30 March, 2023, QC No: Q-91935;* ***Revised:*** *05 April, 2023, Manuscript No: R-91935;* ***Published:*** *12 April, 2023*

Wheat is the countries strategic and second staple crop, has been suffered by different diseases. Among, rusts especially yellow (stripe) rust in highlands and stem (black) rust in mid land potential areas to low lands agro ecologies are economically important and the major limiting factors in wheat production. Wheat genotypes have different response to rust diseases at field condition due to climatic conditions, quantity of pathogen inoculum source and time of infection. The objective of the work was to monitor Ethiopian key location disease nursery for searching against stem rust aimed and targeted environment to wheat stem rust resistance. One thousand four genotypes sources of 157 local cross, 663 CIMMYT introductions, 173 ICARDA materials and 11 commercial cultivars were evaluated for the resistance to stem rust by P-Rep design at Debrezeit Agricultural Research Center of Ethiopian institute of agricultural research, nationally stem rust prone, hot to warm humid areas. Of tested genotypes 1.5%, 1.3%, 2%, 8.2%, 10.6%, 3.3% and 73.1% exhibited immune, resistant to moderately resistant (RMR), moderately resistant (MR), intermediate reaction (MRMS), moderately susceptible (MS), moderately susceptible to susceptible (MSS) and susceptible (S) disease reaction and none of the tested genotypes showed resistant (R) response to stem rust respectively. Thus, genotypes exhibiting with compatible RMR, MR and MRMS disease reactions, are identified as good sources of resistance to stem rust with prodigious significance to achieve current breeding for long-lasting resistance.

Keywords: Wheat, Genotypes, Stem rust, Resistance, Varieties.

Introduction

Ethiopia is the 1st wheat growing country in sub-Saharan Africa, with 2.1 million hectors of land annually with 7.1 million tons of 3.1 t ha^{-1} rain fed and 4t ha^{-1} irrigated production at average yield of 3.05 tha^{-1} (Grote, U., et al., 2021; CSA, 2021). Though, production and productivity of wheat is faced due to different scenarios, of climate change that interfere biotic and abiotic factors that cause huge yield loss (Singh, RP., et al., 2011). Among biotic factors yellow and stem rusts are repeatedly production constraints in wheat growing areas of world including Ethiopia (Murray, G., Brennan, J., 2009).

About 85% of widely grown commercial wheat cultivars from 18 African and Asian countries were found susceptible to wheat rusts. An estimated 52% of total wheat area of 74.6 million hectares planted with wheat signifies 40% of global wheat production is planted with susceptible varieties. Stem and yellow rusts considered a thoughtful intimidations to global wheat production with potentially terrible concerns which could trigger a global food crisis (Zewdie, B., 2016). Thus, rusts are dynamic in nature and a serious problems to wheat production in all cropping season due to favorable climatic conditions, continuous planting of susceptible cultivars in hotspot areas and genetic uniformity of current cultivating mega cultivars favoring chance of evolving new virulent races in Ethiopia (Badebo, A., 2008).

Wheat Stem (black) rust caused by *Puccinia graminici* f.sp.*tritici* is the most bottleneck wheat production constraint that can cause up to 100% yield loss if susceptible cultivars are grown and conducive environment favoured to epidemic occurrence (Hulluka, M.G., et al., 1991; Ayele, B.H., 2002). Extensive surveys revealed that wheat rusts especially stem and yellow rusts caused, 10s of millions of USD annually in in the country. This is due to evolving of new virulent strains which are cold tolerant stem rust races when previously resistant wheat varieties with R-genes are deployed in wider area (Dixon, J., et al., 2009; Badebo, A., et al., 2016). The rapid emergence of virulent races of TTTTF, TTRTF, JRCQC, TKTTF, TTKSK, TTKTF, TTKTT, TTKTK, TKFTF and TKKTF have overcome most of currently released cultivars and known stem rust resistant genes of wheat in Ethiopia (Tadesse, W., et al., 2022). The potential yield losses of 50-100% could be caused by stem and yellow rusts are influenced by timing and severity of diseases outbreak relative to crop growth stage that depends on the rust type, host susceptibility, amount of inoculums, and weather conditions.

To date, for the past five decades more than 88 bread wheat varieties of local cross, CIMMYT and ICARDA origins have been released with continuous progress in yield, acceptable end use qualities and improving disease resistance but, few varieties cover country's wheat growing areas and regrettably most of mega cultivars are becoming out of production due to recurrent rust epidemics. Therefore, considering the above reasons stem rust epidemics and it's out breaks, needs continuous work on monitoring and examining the novel sources of long-lasting resistant wheat genotypes against stem (black) rust. Hence, the present study was carried out to evaluate key location disease nursery for the resistance to wheat stem rust among one thousand four genotypes sourced one hundred fifty seven from local cross, six hundred sixty seven from CIMMYT introductions one hundred seventy three from ICARDA and eleven commercial cultivars.

Materials and Methods

The trial was excuted at Debrezeit Agricultural Research Center that is situated 60 km East of Addis Ababa and geographical extent ranges 8°45' 15" to 8°46' 45" North latitude and 38°46' 45" to 39°01' 00" East longitude and altitude of 1850 meters above sea level. Monthly maximum and minimum temperatures of testing site has 7.4 and 27.7°c with annual rain fall of 801.3 mm. Location represents stem rust prone area with hot to warm humid climate and major wheat production potential agro ecologies of West Shewa, Ethiopia.

Planting materials

A total of one thousand four (1004) genotypes exhibited 157 local cross, 663 CIMMYT introductions, 173 ICARDA sources and 11 commercial varieties were evaluated for the resistance to stem rust. The genotypes were tested at preliminary yield trials and observation nurseries for different traits at quarantine site of kulumsa research center which is national wheat research coordinating center of Ethiopia and advanced lines were selected to test at severely affected hot spot area to stem rust in field condition.

Experimental design

The trail was implemented with partially replicated design consisted of 1508 entries. The spacing of each entry was planted 0.5 m length with 0.2 m row spacing in single row with 26 blocks which was consisted of 58 entries in each blocks. Mixtures of different highly susceptible varieties namely Morocco, PBW343, Hidassie, Digalu and newly susceptible poplar variety Ogolcho were planted in each block as to receive uniform inoculum to the entries. These spreader rows were inoculated by bulk of seven existing known virulent stem rust TTTF, TTRTF, JRCQC, TKTTF, TTKSK, TTKTF and TTKTT pathotypes (races). All agronomic and weed management practice were applied as per recommendations for all entries.

Disease assessment

Disease assessment was performed two times at Debrezeit experimental site at fourteen day's interval, started when susceptible spreader rows reached 30 percent stem rust severity according to modified Cobb scale (Paterson, R.F., et al., 1948). Response of wheat genotypes were assessed through final rust severity (FRS) and coefficient of infection (CI).The host plant response of infection was scored according to Roelfs, A.P., et al., (1992) and average coefficient of infection (CI) was calculated by multiplying the percentage severity and constant value assigned to each reaction type (Wilcoxson, R.D., et al., 1975). The constant values were considered as Immune=0, R=0.2, RMR=0.3, MR=0.4, MRMS=0.6, MS=0.8, MSS=0.9 and S=1.

Results and Discussion

Among one thousand four (1004) tested genotypes, 993 and 11 were advanced bread wheat lines and released commercial cultivars respectively. Thus, genotypes were, 157 local cross, 663 CIMMYT introductions and 173 ICARDA sources, screened for the resistance to stem rust at Debrezeit research center of Ethiopian institute of agricultural research, nationally stem rust prone hot to warm humid areas. The final stem rust severity and response of genotypes were presented in Fig. 1. Fortunately, the season was conducive to stem rust disease epidemics result revealed, various field reactions ranging from immune to susceptible (s) response were exhibited at experimental site. Out of 1004 tested genotypes 1.5%, 1.3%, 2%, 8.2, 10.6%, 3.3% and 73.1% showed immune, resistant to moderately resistant (RMR), moderately resistant (MR), intermediate reaction (MRMS), moderately susceptible (MS), moderately susceptible to susceptible (MSS) and susceptible (S) disease reaction and none of the tested genotypes showed resistant (R) response to stem rust respectively at Debrezeit experimental site (Fig. 1).

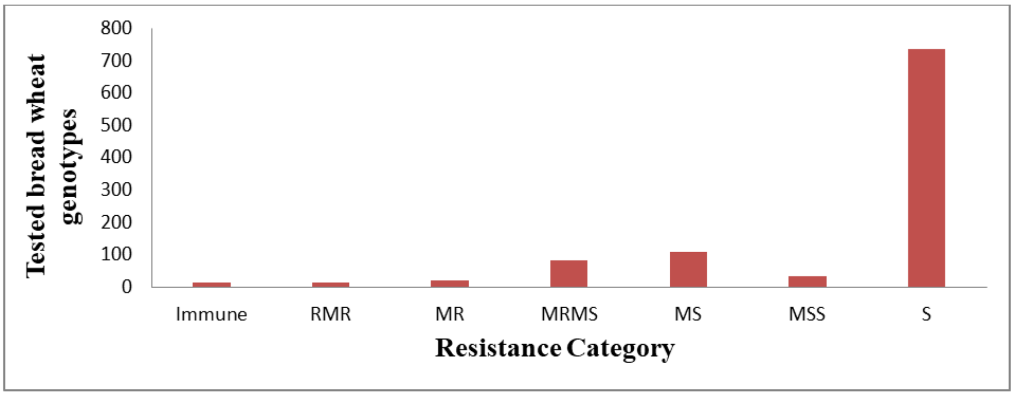

Fig. 1. Response of genotypes to stem rust at Debrezeit in 2022.

Despite highest stem rust epidemics at Debrezeit, 113 genotypes were selected which 33 of them exhibiting final rust severities ranging from 5 to 10% with compatible RMR and MR disease reaction, are great importance to attain current breeding for long-lasting resistance (Parlevliet, J.E., 1988) (Table 3), whereas fifteen genotypes showed immune type response with zero disease severity may be race-specific or unstable resistance by a test in which a number of host genotypes are tested against a number of pathogen genotypes and along with cultural control measures and targeted use of pesticides, as part of an IPM strategy to be added for implementation (Table 2). On the other hand eighty two genotypes were also selected which showed intermediate response to stem rust at tested site (Table 4). unfortunately none of the released check cultivars showed R, RMR, MR and MRMS type of field reaction which exhibited susceptible to very susceptible varietal response and should be supported by frequent application of effective fungicides (Table 1).

The available resistant genes in these selected genotypes overcome stem rust virulence in the field (tables 3 and 4) and led to statistically low rust severities in spite of well-suited host pathogen reactions (Nzuve, F.M., et al., 2012). According to van der Plank's (Van Der Plank, J.E., 1968) and Robinson's (Robinson, R.A., 1979) attempts, Horizontal, uniform, race-non-specific or stable resistance could be built up in crops as a primary objective and as the foundation of disease management. According to Van der Plank's test for horizontal resistance (tables 3 and 4) appears to be a simple and sound way to test for polygenic inheritance of resistance (Parlevliet, J.E., Zadoks, J.C., 1976).

According to Sarah (2013), economic importance of finding and searching of resistant genes from old and new released commercial cultivars of wheat to stem rust as valuable tool.

Table 1. Response of check varieties to stem rust at Debrezeit Agricultural research center.

Varietey	Stem rust Severity	Field Response
Balcha	80	very susceptible
Deka	80	very susceptible
Danda'a	80	very susceptible
Hidase	90	very susceptible
King bird	80	very susceptible
Morocco	90	very susceptible
Ogolcho	90	very susceptible
Pavon-76	80	very susceptible
PBW343	90	very susceptible
Alidoro	50	Susceptible
Boru	60	Susceptible

Table 2. Response of wheat genotypes showed immune resistance to stem rust at Debreziet in 2022.

Genotypes	Sev (%)	Rxn	Genotypes	Sev (%)	Rxn	Genotypes	Sev (%)	Rxn
EBW160044	0	immune	EBW202411	0	immune	EBW212985	0	Immune
EBW160120	0	immune	EBW202466	0	immune	EBW213122	0	Immune
EBW192938	0	immune	EBW212367	0	immune	EBW213129	0	Immune
EBW202251	0	immune	EBW212368	0	immune	EBW214064	0	Immune
EBW202255	0	immune	EBW212749	0	immune	EBW223045	0	Immune

Seve (%)-percent severity, Rxn-response of wheat genotypes to stem rust.

Table 3. Response wheat genotypes identified for slow rusting resistance to stem rust at Debreziet.

Genotypes	Sev (%)	rxn	Genotypes	Sev (%)	Rxn	Genotypes	Sev (%)	Rxn
EBW150047	10	MR	EBW160055	5	RMR	EBW212292	5	MR
EBW160013	10	MR	EBW160089	5	RMR	EBW212303	5	RMR
EBW160014	10	MR	EBW160090	5	MR	EBW212307	5	RMR
EBW160016	5	MR	EBW160102	5	MR	EBW212400	5	RMR
EBW160017	5	RMR	EBW160104	5	MR	EBW212483	5	MR
EBW160023	5	RMR	EBW160109	5	MR	EBW212559	5	RMR
EBW160025	5	R	EBW160115	5	MR	EBW212583	5	MR
EBW160034	5	MR	EBW202020	5	RMR	EBW212684	5	RMR
EBW160037	5	MR	EBW202048	5	RMR	EBW212724	10	MR
EBW160052	5	MR	EBW212156	10	MR	EBW214010	5	MR
EBW160054	5	MR	EBW212229	5	MR	EBW214198	5	RMR

Sev (%)-percent severity, Rxn-response of wheat genotypes to stem rust.

Table 4. Wheat genotypes showed intermediate resistance to stem rust at Debreziet in 2022 (82).

Genotypes	Sev (%)	rxn	Genotypes	Sev (%)	Rxn	Genotypes	Sev (%)	Rxn
EBW150062	20	MRMS	EBW160099	10	MRMS	EBW212154	10	MRMS
EBW150166	10	MRMS	EBW160101	10	MRMS	EBW212155	10	MRMS
EBW150167	5	MRMS	EBW160103	10	MRMS	EBW212159	10	MRMS
EBW150171	20	MRMS	EBW160105	10	MRMS	EBW212231	30	MRMS
EBW150181	20	MRMS	EBW160106	20	MRMS	EBW212261	20	MRMS
EBW150182	30	MRMS	EBW160107	20	MRMS	EBW212266	30	MRMS

EBW160001	10	MRMS	EBW160113	30	MRMS	EBW212271	20	MRMS
EBW160003	30	MRMS	EBW160121	5	MRMS	EBW212283	40	MRMS
EBW160004	20	MRMS	EBW160127	10	MRMS	EBW212354	20	MRMS
EBW160005	20	MRMS	EBW160130	30	MRMS	EBW212371	40	MRMS
EBW160012	5	MRMS	EBW160131	20	MRMS	EBW212374	20	MRMS
EBW160020	40	MRMS	EBW160134	20	MRMS	EBW212390	40	MRMS
EBW160024	20	MRMS	EBW160137	10	MRMS	EBW212407	20	MRMS
EBW160027	20	MRMS	EBW160138	20	MRMS	EBW212558	10	MRMS
EBW160028	20	MRMS	EBW192350	20	MRMS	EBW212571	10	MRMS
EBW160038	20	MRMS	EBW202164	5	MRMS	EBW212573	10	MRMS
EBW160042	10	MRMS	EBW202168	20	MRMS	EBW212574	10	MRMS
EBW160048	10	MRMS	EBW202174	10	MRMS	EBW212683	10	MRMS
EBW160053	20	MRMS	EBW202175	20	MRMS	EBW212709	10	MRMS
EBW160057	20	MRMS	EBW202381	10	MRMS	EBW212723	30	MRMS
EBW160069	50	MRMS	EBW202400	20	MRMS	EBW212798	30	MRMS
EBW160070	10	MRMS	EBW202463	10	MRMS	EBW212814	20	MRMS
EBW160073	30	MRMS	EBW202476	30	MRMS	EBW212815	30	MRMS
EBW160078	40	MRMS	EBW202484	10	MRMS	EBW214026	30	MRMS
EBW160082	40	MRMS	EBW202507	30	MRMS	EBW214058	30	MRMS
EBW160086	20	MRMS	EBW202566	20	MRMS	EBW224006	10	MRMS
EBW160091	5	MRMS	EBW212029	10	MRMS			
EBW160095	10	MRMS	EBW212060	10	MRMS			

Sev (%)-percent severity, Rxn-response of wheat genotypes to stem rust.

Conclusion

Updating commercial cultivars by new improved resistant and high yielding varieties are the most economical, effective, and environmentally friend and sustainable disease management strategy particularly for wheat rust diseases. Results revealed that genotypes that exhibited with compatible RMR, MR and MRMS disease reactions with attainable yield advantages are identified as good sources of resistance and provide valuable information to stem rust with great importance to attain current breeding program for releasing new resistant varieties.

Acknowledgment

We kindly thank Debrezeit Agricultural Research Center for hosting experimental field, Ethiopian institute of Agricultural Research (EIAR), and Kulumsa Agricultural Research Center (KARC) for logistic provision of the study and Modernizing EIAR on Crop Improvement (MERCI) for financial support.

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Citation:

Zerihun, A.A., Habtamariam, D.K., Abebele, G.M., Gure, T.N., Endale, H.Z. (2023). Evaluation of Ethiopian key location disease nursery for the novel sources of resistance to stem rust (*Puccinia graminis* f. s. *tritici*). *Ukrainian Journal of Ecology.* 13:58-63.