International Journal of Economic Plants

https://ojs.pphouse.org/index.php/IJEP

Crossref

IJEP August 2024, 11(3): 310-315

Article IJEP5452a

Full Research

Doi: HTTPS://DOI.ORG/10.23910/2/2024.5452a

Phenotypic Screening of Bread Wheat (*Triticum spp* L.) Germplasm Collection for Yellow and Leaf Rust Disease Resistance

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Article History

Received on 13th May, 2024

Received in revised form on 08th August, 2024

Accepted in final form on 17th August, 2024

Abstract

The Research was conducted at KARC during June to November, 2023 to phenotypic screening of bread wheat genotypes for yellow and leaf rust resistance. Both rusts were recorded based on the modified Cobb scale. Severity of yellow rust showed from immune to 70%. 826 genotypes showed slow rusting resistance ranging from 0–30%), 575 genotypes observed as slow rusting plant resistance ranging from 31–50%) and 96 genotypes observed as low adult plant resistance (>50% of yellow rust severity). Tested genotypes showed diverse reactions for yellow rust ranging from immune to susceptible responses. 57 genotypes were observed immune, 161 genotypes were showed moderately resistant reaction type. 317 genotypes were observed moderately susceptible reaction and 962 genotypes were observed susceptible reactions for yellow rust response. The leaf rust severity of the studied genotypes showed from immune to 90. 607 genotypes (showed slow rusting resistance ranging from 0–20% of severity), 563 genotypes observed as slow rusting plant resistance ranging from 21–50% of severity) and 326 genotypes observed as low adult plant resistance (>50% of leaf rust severity. Tested genotypes showed diverse reactions for leaf rust ranging from immune to susceptible responses. 58 genotypes were observed immune, 30 genotypes were observed moderately resistant, 80 genotypes were observed moderately resistant to moderately susceptible, 464 genotypes were showed moderately susceptible reaction, 864 genotypes were showed susceptible reactions for leaf rust disease response. Based on yellow rust, leaf rust and agronomic performance 76 genotypes were selected for the next breeding step.

Keywords: Disease resistance, leaf rust, *Triticum aestivum*, yellow rust

1. Introduction

Wheat (Triticum aestivum L.), is a self-pollinating annual plant, the grass family, Gramineae, is extensively grown for staple food in the world (Mollasadeghi and Shahryari, 2011; Nishant et al., 2018). Wheat is not only the most important food security crop but also it is currently becoming strategic as a cash crop at the global level (Tadesse et al., 2017; Crespo-Herrera et al., 2018). World wheat production is based almost entirely on two modern species: common or hexaploid bread wheat (Triticum aestivum L, 2n=6x=42, AABBDD) and durum or tetraploid wheat (T. turgidum subsp. durum, 2n=4x=28, AABB) (Feldmann, 2001). World wheat prouduction is reached at 786,701 million metric ton in 2022/2023, and wheat production is leading by China (136,590) stand frist, European Union (133,650) second and thrid India (110,554) million metric ton respectively (Anonymous, 2024).

Ethiopia is primary largest wheat producer country in Africa (Yasin, 2015; Regasa, 2019).Wheat ranks second in 2021/22 cropping season both in terms of yield production (5.81 million tons) and area coverage (1.87 mha) following maize among cereals for rain fed production in Ethiopia (Anonymous, 2022). Wheat production in Ethiopia for 2021/22 is projected to 5.18 mt, up by 1.6 percent over the 2020/21 production estimated. This is due to more Government of Ethiopia engagement in irrigation, better input supply, and mechanized farming in the lowland and central parts of the country (Anonymous, 2021). However, wheat production and productivity is relatively small compare to global standards. The main reason is that mostly subsistence farming of wheat is produced by small-scale farmers through rain feed production system with less irrigated production (Adugnaw and Dagninet, 2020) and constrained by several infectious diseases including rusts (Yellow rust, stem rust and leaf rust) and Septoria leaf blotch diseases which are the major problem of wheat production in Ethiopia (Kassa et al., 2015; Endale and Getaneh, 2015; Tadesse et al., 2017).

Yellow rust is the most important fungal diseases of wheat and the major production challenges in the major wheat producing regions of Ethiopia (Ayele et al., 2008a). Wheat yellow rust disease caused by Puccinia striiformis f. sp. tritici is one of the most threat and wheat production problem in the highland areas of Ethiopia (Ayele et al., 2008a; Alemu and Muche 2019). Wheat leaf rust caused by Puccinia triticina Eriks., is the most widespread foliar disease

in wheat worldwide. It occurs annually in a wide range of environments causing significant yield losses (more than 50%) under favorable field conditions on the susceptible wheat genotypes (German et al., 2007). The solution for the yield loss by yellow and stem rust diseases are develop resistance bread wheat variety or appropriate use of fungicide chemicals. But develop the resistance variety is the best mechanism to control the rusts. Resistance to wheat rusts is generally categorized into two types, race-specific and race non-specific. Race-specific resistance is generally qualitative and usually short-lived due to the evolution of potentially virulent pathogens (Wellings, 2011). In contrast, adequate levels of race non-specific resistance involve genes which might contribute from minor to intermediate effects. Plants carrying this type of resistance are susceptible at the seedling stage but express resistance at the post-seedling stages of plant growth. This characteristic is called slow rusting and often associated with some forms of adult plant resistance (Lagudah, 2011). Hence, the present study designed to phenotypic screen of bread wheat genotypes for yellow and leaf rust resistance in the natural field condition.

2. Materials and Methods

2.1. *Experimental site and year*

The experiment was conducted at Kulumsa agricultural research center in 2023 (June to November) main cropping season. Kulumsa agricultural research center is located at 08^{o}01’10” N longitude and 39^{o}09’11” E latitude at an altitude of 2200 meters above sea level. The mean annual rain fall of Kulumsa is 820 mm with an average annual temperature of 16.5°C.

2.2. *Experimental materials and design*

The materials consisted of 1500 bread wheat genotypes planted in two rows with two meters long, 20 Centimeters spacing between rows and arranged in augmented design without check. The materials were collected from Ethiopian biodiversity institute (EBI) presented in Table 1.

2.3. *Disease scoring*

To evaluate these genotypes for yellow and Leaf rust diseases scoring were made for both yellow and leaf rust. Host responses to both rusts were recorded based on the modified Cobb scale (Peterson et al., 1948). This scale combines several infection types; resistant (R), moderately resistant (MR), moderately susceptible (MS), moderately Resistant to Moderately Susceptible (MRMS) and susceptible (S). Severity was recorded on 0–100% scale where 0% was considered as immunity while 100% was completely susceptible.

3. Results and Discussion

3.1. *Rust severity and response*

The evaluation of yellow rust severity in the studied bread wheat genotypes revealed a diverse range of responses, with scores varying from complete immunity (0% severity) to significant susceptibility (70% severity) (Figure 1, 2 and Table 1). This diversity highlights the presence of a wide spectrum of resistance levels within the tested germplasm.

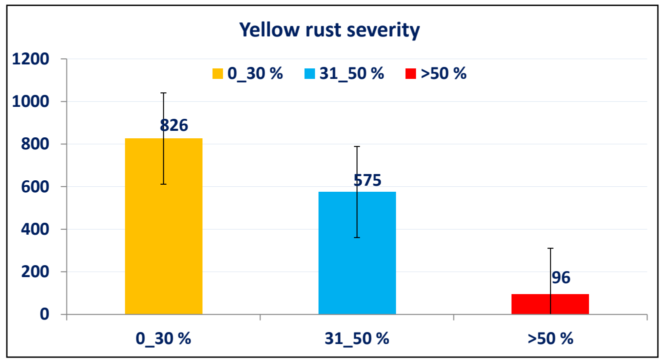

Figure 1: Level of yellow rust severity

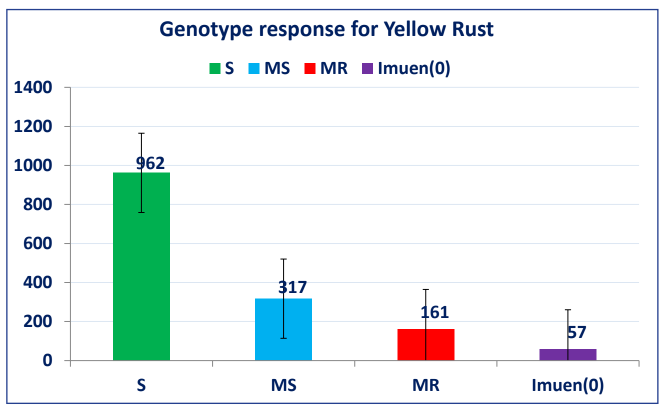

Figure 2: Tested genotype response for yellow rust

A noteworthy finding of this study was the prevalence of slow rusting resistance among the genotypes. A total of 826 genotypes (55.18%) exhibited slow rusting resistance, characterized by yellow rust severity ranging from 0% to 30%. An additional 575 genotypes (38.41%) displayed a similar slow rusting response, with severity levels between 31% and 50%. These findings suggest that a substantial portion of the tested germplasm possesses inherent mechanisms for suppressing the development of yellow rust disease to a moderate degree. This type of resistance is particularly valuable because it offers durable protection against a broader range of yellow rust pathogens compared to race-specific resistance, which can be

Table 1: Disease Severity and Selected Genotypes Response for Yellow Rust and Leaf Rust

Sl. No.	Genotype	YrS	YrR	LrS	LrR	Sl. No.	Genotype	YrS	YrR	LrS	LrR
1.	216581	20	MS	15	MS	39.	232036	20	MS	5	MS
2.	226218	40	S	0	0	40.	231644	50	S	20	MS
3.	226251	40	S	5	MRMS	41.	232034	20	MS	15	MS
4.	222454	30	S	10	MRMS	42.	232001	20	MS	5	MR
5.	226404	30	S	10	MRMS	43.	231897	30	S	5	MS
6.	222455	40	S	20	S	44.	232025	15	MRMS	1	MR
7.	222656	40	S	0	0	45.	232085	20	MS	5	MS
8.	222777	50	S	20	MS	46.	231611	30	S	10	MS
9.	222568	40	S	30	S	47.	231703	40	S	30	S
10.	226663	60	S	30	S	48.	232175	50	S	40	S
11.	226631	50	S	20	MS	49.	231763	30	S	20	MS
12.	226932	40	S	15	MRMS	50.	31962	20	MS	5	MS
13.	226883	50	S	0	0	51.	31947	20	MS	20	MS
14.	226939	40	S	15	MS	52.	31939	10	MS	5	MS
15.	226933	40	S	15	MRMS	53.	31941	30	S	10	MS
16.	226918	40	S	15	MS	54.	31975	10	MS	5	MS
17.	226944	1	MR	5	MRMS	55.	31546	10	MS	1	MR
18.	232124	30	S	50	S	56.	33214	40	S	30	S
19.	232129	50	S	30	S	57.	33972	10	MS	20	MS
20.	231758	10	MRMS	10	MRMS	58.	33924	40	S	40	S
21.	231760	10	MSMR	15	MRMS	59.	33435	10	MS	20	MS
22.	231762	20	MS	10	MRMS	60.	33444	40	S	40	S
23.	234483	30	S	30	S	61.	34248	40	S	60	S
24.	231939	20	MS	5	MR	62.	34623	20	MS	60	S
25.	232053	30	S	30	S	63.	34558	20	MS	60	S
26.	234486	50	S	0	0	64.	36396	30	S	90	S
27.	231626	50	S	20	MS	65.	36440	1	MR	30	MS
28.	231931	40	S	30	S	66.	36538	5	MS	30	MS
29.	231863	15	MRMS	20	MS	67.	36519	5	MS	40	S
30.	231949	20	MS	10	MRMS	68.	36951	1	MR	60	S
31.	234523	50	S	0	0	69.	36506	10	MRMS	50	S
32.	231950	20	MS	10	MRMS	70.	36486	1	MR	50	S
33.	231780	20	MRMS	10	MS	71.	36420	1	MR	50	S
34.	234587	20	MS	5	MS	72.	36417	0	0	60	S
35.	231913	10	MRMS	5	MR	73.	37307	1	MS	50	S
36.	232163	15	MRMS	5	MS	74.	37323	1	MR	80	S
37.	231882	30	S	20	MS	75.	37262	0	0	60	S
38.	232037	10	MRMS	5	MS	76.	226379	15	MS	20	MS

YrS: Yellow Rust Severity; YrR: Yellow Rust Response; LrS: Leaf Rust Severity; LrR: leaf Rust Response; MR: Moderately Resistance; MS: Moderately Susceptible; MRMS: moderately Resistant to Moderately Susceptible; S: Susceptible overcome by evolving pathogen populations (Lagudah, 2011).

The study also identified a subset of genotypes exhibiting immune (0% severity) and susceptible (S) responses to yellow rust. A total of 57 genotypes (3.81%) displayed complete immunity, indicating the presence of highly resistant genes within the germplasm pool. These immune genotypes represent valuable breeding resources for developing new wheat varieties with robust resistance to yellow rust. Conversely, 962 genotypes (64.26%) were classified as susceptible, demonstrating a significant level of vulnerability to yellow rust infection. This highlights the ongoing challenge posed by yellow rust disease and the need for continued efforts to develop and deploy resistant wheat varieties for enhanced food security in Ethiopia.

The findings of this study align with previous research conducted by Ayele et al. (2021), Bayisa et al. (2023), Shiferaw et al. (2020), Shewaye et al. (2021), and Mohammadi et al. (2023). These studies also reported a broad spectrum of yellow rust severity and reaction types among bread wheat genotypes. This consistency across various research efforts reinforces the notion that wheat germplasm exhibits a natural variation in response to yellow rust disease.

Building on these results, further investigations are recommended to delve deeper into the underlying genetic mechanisms of resistance observed in the slow rusting and immune genotypes. Molecular marker analysis can be employed to identify specific genes associated with resistance, enabling breeders to incorporate these traits into new breeding lines. Additionally, exploring the interaction between these resistant genotypes and various yellow rust pathogen isolates can provide valuable insights into the durability of the observed resistance under field conditions. By integrating these findings with breeding programs, researchers can develop effective strategies for controlling yellow rust disease and ensuring sustainable wheat production in Ethiopia.

The evaluation of leaf rust severity in the studied bread wheat genotypes revealed a wide range of responses, with scores spanning from complete immunity (0% severity) to significant susceptibility (90% severity) (Figure 3, 4 and Table 1). This diversity reflects the presence of a spectrum of resistance levels within the tested germplasm.

Similar to the findings for yellow rust, a significant portion of the genotypes (40.57% or 607 genotypes) exhibited slow rusting resistance for leaf rust, with severity levels ranging from 0% to 20%. An additional 37.63% (563 genotypes) displayed slow rusting resistance with severity between 21% and 50%. These results suggest that a substantial proportion of the tested germplasm possesses inherent mechanisms that can suppress the development of leaf rust disease to a moderate degree. As with yellow rust, slow rusting resistance offers a valuable advantage because it provides broader protection against a wider range of leaf rust pathogens compared to race-specific resistance (Lagudah, 2011).

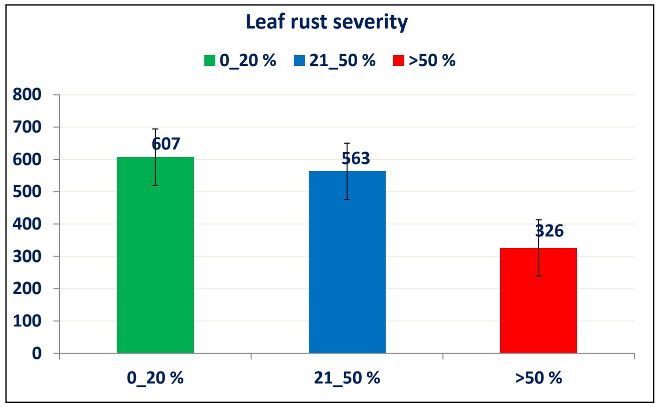

Figure 3: Level of leaf rust severity

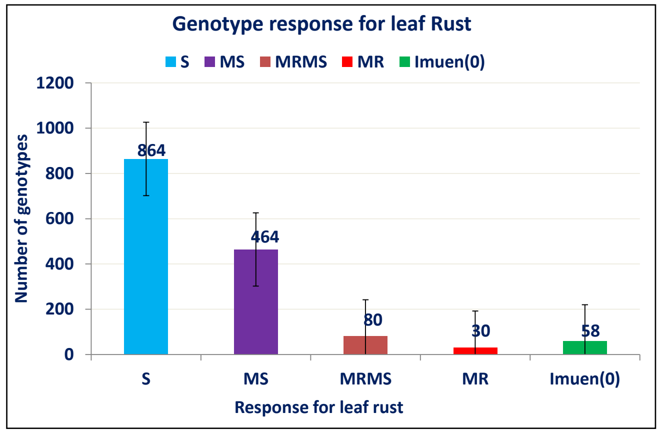

Figure 4: Tested genotype response for Leaf rust

The study also identified a subset of genotypes exhibiting immune (0% severity) and susceptible (S) responses to leaf rust disease. A total of 58 genotypes (3.88%) displayed complete immunity, indicating the presence of highly resistant genes within the germplasm pool. These immune genotypes represent crucial breeding resources for developing new wheat varieties with durable resistance to leaf rust. In contrast, 864 genotypes (57.75%) were classified as susceptible, highlighting a significant level of vulnerability to leaf rust infection. This underscores the ongoing challenge posed by leaf rust disease and emphasizes the need for continued efforts to develop and deploy resistant wheat varieties for enhanced food security in Ethiopia.

The findings of this study are consistent with previous research conducted by El-Orabey (2018) and Draz et al. (2015). These studies also reported a broad spectrum of leaf rust severity and reaction types among bread wheat genotypes. This consistency across various research efforts reinforces the concept that wheat germplasm exhibits a natural variation in response to leaf rust disease.

The categorization of slow rusting and low adult plant resistance based on severity percentages aligns well with the classification system proposed by Pathan and Park (2006). They categorized the level of adult plant resistance (APR) as high, medium, and low based on severity scores. This alignment facilitates the comparison of findings from this study with previous research and establishes a standardized framework for interpreting leaf rust resistance levels in bread wheat genotypes.

Building on these results, further investigations are recommended to gain a deeper understanding of the genetic mechanisms underlying the resistance observed in the slow rusting and immune genotypes. Molecular marker analysis can be employed to identify specific genes associated with resistance, enabling breeders to incorporate these traits into new breeding lines. Additionally, exploring the interaction between these resistant genotypes and various leaf rust pathogen isolates can provide valuable insights into the durability of the observed resistance under field conditions. By integrating these findings with breeding programs, researchers can develop effective strategies for controlling leaf rust disease and ensuring sustainable wheat production in Ethiopia.

4. Conclusion

Yellow rust and leaf rust severity of the studied genotypes showed from immune to 70% and 90% respectively. Tested genotypes showed diverse reactions for yellow and leaf rust ranging from immune to susceptible responses. Based on yellow rust, leaf rust and agronomic performance 76 genotypes were selected for the next breeding step.

5. Acknowledgement

The authors would like to express gratitude for Ethiopian Institute of Agricultural Research and Kulumsa Agricultural Research Center and we are also grateful to EBI for its support in providing experimental materials to conduct this study. We would like to thank Mr Nigussie Degefa, Mr. Mamuye Tesema, Mrs. Banchi Simie and mrs. Etenesh Melese for their supports.

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