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Evaluation of Ethiopian Durum Wheat Varieties and Landrace Cultivars for the Adult Plant Resistance of Wheat Leaf Rust (*Puccinia triticina*)

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ABSTRACT

Wheat Leaf rust caused by the pathogen Puccinia triticina is a serious threat of wheat production in Ethiopia, yield loss due to this disease reached up to 70%. A study was carried out to identify leaf rust adult plant resistance in commercial durum wheat cultivars and landraces. 35 durum wheat Varieties and 200 durum wheat landraces with three susceptible checks arranged in Augment design and evaluated against leaf rust at Debere Zeit Agricultural Research Center, Ethiopia during the 2017/18 main season. Terminal Rust Severity (TRS), Coefficient of Infection (CI), Area under Disease Progress Curve (AUDPC) and Disease Progress Rate (DPR) were used to measure leaf rust adult plant resistance in the test materials. Analysis of all disease parameters was carried out using SPAD software. There were highly significant differences (P<0.01) for all disease parameters among the test cultivars. Above half of evaluated Varieties and landraces (57.9 %) showed better Adult plant resistance under high disease pressure. From the total of 235 tested Varieties and landraces, 136 had slow rusting resistance of which 14 were released varieties and the rest 122 were landraces. Four commercial Varieties (Selam, Mossobo, Bekelcha, and Utuba) and a landrace cultivar (Mcd4-32) had high levels of field resistance with very low AUDPC, ACI, and TRS with MR infection type; hence, they may carry major resistance gene (s). However, the rest 99 Varieties and landraces exhibited high to moderate level of slow rusting resistance with MS responses and may have adult plant resistance controlled by minor resistance genes. The slow rusting cultivars identified from the current study can be used for further manipulation in wheat improvement programs.

Keywords: *Adult plant resistance, Durum wheat, Leaf rust, Puccinia triticina.*

1. INTRODUCTION

Wheat is staple food crops that provide 20% of protein and calories for human consumption worldwide [1]. The demand for wheat is projected to grow over the coming decades [2]. However, World wheat productivity is growing at 1% rate.

Wheat is important crops in Ethiopia, represent 14% of caloric intake, i.e. second important food crop [1]. In area of cultivation, fourth crop in Ethiopia [3]. In rapidly urbanizing Sub-Saharan Africa, wheat consumption is expected to grow by 38% by 2023 [4]. Demand steadily increased in Ethiopia particularly due to the emergence of many food processing industries [3].

Use of crop diversity is a key approach to improve productivity and achieve food security [5]. Ethiopian durum wheat landraces are diverse and possess high variation but not exploited [6]. Ethiopian landraces contributed to world wheat improvement for instance, the Ethiopian durum wheat landrace *ST464* was one of the major sources of *Sr13* [7]. In Ethiopia, more than 90 bread and 36 durum wheat varieties have been released for production since 1950s. However, the national average yield is still 2.78 t/ha, which is far less than potential yields of 8 to 10 t/ha [8].The average yield of durum wheat is even less i.e. 1.3 t/ha. The low productivity is attributed to lack of resistant varieties to the prevalent wheat rusts.

Leaf rust, caused by *Puccinia triticina* has been one of the most important diseases in Ethiopia [9]. Leaf rust is important disease, especially on durum wheat, losses reaching up to 70% on susceptible cultivars [10-12,]. In Ethiopia, most of the research works on wheat diseases have been focused on yellow and stem rusts. Research works on host pathogen interactions in durum wheat to leaf rust pathogen are limited. Thus, identification of resistance sources from durum varieties and landraces would be essential for resistance breeding and variety deployment. Therefore, the objective of the study was: Identify sources of adult plant resistance for leaf rust in Ethiopian durum wheat varieties and landraces.

2. MATERIALS AND METHODS

2.1. Descriptions of the Study Area

The experiment was conducted in a black soil at Debre Zeit Agricultural Research Center, Ethiopia. Debre Zeit is located in East Shewa Administrative Zone of the Oromia National Regional State 47 km southeast of Addis Ababa, at 38°57' E longitude and 08°44' N latitude, with an elevation of 1900 m.a.s.l [13]. It receives an annual average rainfall of 851 mm, and has an annual temperature range of 8.9 -28.3 ^{o}C, with 61.3% mean annual relative humidity [15].

2.2. Planting Materials

A total of 200 durum wheat landraces, 35 durum wheat varieties, and 3 susceptible checks used for adult plant resistance against leaf rust at Debre zeit during 2017/18 main season. The planting materials obtained from Debre zeit Agricultural Research Center. The 35 durum wheat varieties released in Ethiopia from 1976 to 2015. The susceptible checks were Morocco (bread wheat), Local Red, and Arendeto (both durum wheat).

2.3. Plot Size and Design

The experiment was arranged in an augmented design, and each plot consists of two rows with plot size of 1 m x 0.2 m and with a spacing of 0.4 m between plots and 1 m between blocks. Seeding rate, fertilization, weeding and other management practices applied according to the recommendations for the area. To ensure uniform spread of inoculum and for sufficient disease development during the trial periods, the susceptible wheat cultivar ‘Morocco’ was planted a week earlier around the experimental areas. Artificial inoculation was carried out by spraying a mixture of leaf rust spores suspended in mineral oil [16].

2.4. Data Collection and Analysis

Disease severity was scored by estimating the approximate percentage of leaf area affected using modified Cobb scale [14]. Disease severity recorded from all plots six times in 10-days interval starting from the onset of leaf rust on the susceptible checks. The host plant responses (infection types) scored according to [16].

Average coefficient of infection (ACI) calculated by multiplying the percentage severity and the constant value assigned to each reaction type [17]. The constant values were considered as R (Resistant) = 0.2, MR (moderately resistant) = 0.4, M (intermediate) =0.6, MS (moderately susceptible) =0.8 and S (susceptible) =1.

The area under the disease progress curve (AUDPC) for each plot calculated from the multiple leaf rust severity scorings. Area under disease progress curve (AUDPC) calculated using the formula suggested by [17].

$$AUDPC = \sum_{i=1}^{n-1} \left(\left(\frac{x_i + x_i + 1}{2}\right) \ (t_i + 1 - t_i) \right)$$

Where, xi = the disease severity of ith record, X_i+1 = the disease severity of i+1th record and t_i+1 - ti = Number of days between the ith record and i+1th record, and n = number of observations.

Disease progress rate (DPR) as a function of time was calculated from disease severity observations by using Gompertz model adopted by Van der Plank (1963). dy/dt = yo +rGt where dy/dt = absolute disease rate rGt= rate of infection, yo = amount of disease. Each severity data were transformed to -ln [-ln (yo)], where ln =lan, yo = disease severity in decimal form for each observation time.

The coefficient of infection (CI), terminal rust severity (TRS), Area under disease progress curve (AUDPC), and Disease progress rate (DPR) were analyzed using SPAD software [18]. Means that differ significantly separated using critical difference in each

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category viz., checks, test entries, tests and checks. Correlation analysis was made among the different disease parameters (TRS, AUDPC, ACI, and DPR).

3. RESULT AND DISCUSSIONS

3.1. Analysis of Variance

The analysis of variance (ANOVA) for different leaf rust resistance parameters is shown in Table 1. There was highly significant (p<0.01) difference among the test materials for all slow rusting parameters. In separate comparison of test cultivars Vs checks the analysis of variance showed highly significant (P<0.01) differences for all parameters. The test cultivars have also showed highly significant (p<0.01) difference for all parameters. There were highly significant difference (p<0.01) among the check cultivars for all slow rusting parameters. Selection of genotypes for slow rusting resistance is possible, because genotypes were significantly different.

Table 1. Mean Squares of Slow Rusting Parameters

Mean Squares	**Slow rusting parameters**			
	TRS	**ACI**	**AUDPC**	**DPR**
Block (12)	75.5NS	59.8**	1480442**	0.004NS
Treatments(271)	163.8**	114.3**	215910**	0.0053**
Checks(3)	2302.8**	1607.4**	3349483**	0.00064**
Test cultivars (235)	124.5**	82.8**	155837.5**	0.0054**
Test cultivars and checks (238)	5062.1**	4506.1**	8022937.9**	0.0055**
Error	54.3	14.5	35140.4	0.00024
CV (%)	14.7	13.2	11.7	4.9

**=highly significant (p<0.01), NS= non-significant, TRS= terminal rust severity, ACI= average coefficient of infection, AUDPC= area under disease progress curve, DPR= disease progress rate, CV = coefficient of variation.

3.2. Terminal rust severity

There was wide variation in the leaf rust terminal rust severity ranging from 10 to 70%. Diverse host reactions also observed ranging from resistance (R) to Susceptible (S).Terminal rust severity represents the cumulative result of all resistance factors during the progress of epidemics [19]. Based on terminal rust severity the tested durum wheat cultivars were grouped in to three groups of slow rusting resistance, that is high, moderate, and low level of resistance, having 1-30, 31-50% and above 50% respectively [20].

Despite the heavy leaf rust disease pressure, 25 tested durum wheat cultivars namely; *Megenagna, Selam, Mossobo, Bekelcha, Utuba, Mcd3-19, Mcd4-32, Mcd4-11, Mcd4-12, Mcd4-28, Mcd5-35, Mcd7-42, Mcd8-45, Mcd8-10, Mcd10-9, Mcd10-6, Mcd11-9, Mcd11-31, Mcd11-18, Mcd12-5, Mcd13-34, Mcd15-38, Mcd15-27, Mcd16-4* and *Mcd16-50* exhibited high level of slow rusting resistant with moderately susceptible to moderately resistance response. Genotypes with slow rusting resistance are greatly important to achieve effective breeding for durable resistance to leaf rust [21 and 22]. According to [21], the availability of resistance genes in the genotypes overcome the prevailed virulence leaf rust pathogens in the field and led to statistically low disease severity, despite the compatible host pathogen reactions. Previously, [23, 24, 20, and 26] used terminal rust severity to evaluate slow rusting in wheat cultivars.

On the other hand, 171-durum wheat cultivars showed terminal rust severity between 31 and 50%, of these 20 were released wheat varieties and 151 were landraces and were regarded as possessing moderate level of slow rusting resistance. The rest 39 cultivars, of these 10 released varieties and 29 landraces exhibited above 50% Terminal rust severities, which had no slow rusting resistance. From the three susceptible checks *Arendeto* was not demonstrate susceptibility while *Morocco* and *Local red* displayed the highest disease severities of 70 to 80% with completely susceptible responses, indicating that an acceptable epidemic pressure was established.

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Table 2. Durum Wheat Cultivars Having Adult Plant Resistance

S. No	Cultivars	Pedigree	ACI	TRS	rAUDPC	DPR
1	**Mossobo**	BHA/u/nv//2**E#24	5.3	20	20.3	0.015
2	**Bekelcha**	98OSNGedilfa/Guerou	6	30	22.3	0.079
3	**Selam**	61130/Lds//G11's'/3/cit's'/4/Hora/3/Megrbce's'	3.3	30	22.4	0.079
4	**Utuba**	Omruf1/Stojocri2/3/1718/BreadWheat24//Karim	5.3	20	20.3	0.015
5	**Megenagna**	Dz04-1167/Dz129/yemen/cit's'/pls's'/3/ TaganrogB.B/4/5/chen's'/RCHI//Hui's'/BHA	8.6	20	20.3	0.015
6	**Mcd4-32**	Landrace	5.3	30	22.3	0.015
7	**Mcd7-42**	Landrace	6.7	30	19.3	0.27
8	**Mcd4-12**	Landrace	8.3	30	29.5	0.28
9	**Morocco**	Susceptible check	43	63	90.3	0.31

ACI=Average Infection coefficient, TRS= Terminal rust severity, rAUDPC= relative Area under disease progress curve, DPR= Disease progress rate.

3.3. Coefficient of infection

The data on disease severity and host reaction were combined to calculate coefficient of infection (CI). According to [27] cultivars with coefficient of infection values of 0-20, 21-40, and 41-60 regarded as possessing high, moderate, and low level of slow rusting resistance respectively. In this study, 17 durum wheat cultivars *(Cocorit-71, Gerardo, LD-357, Foka, Kilinto, Tob-66(Arsi robe), Ginchi, Yerer, Megenagna, Selam, Mossobo, Ejersa, Bekelcha, Obsa, Flakit, Mangudo, Utuba)* and 31 landraces *(Mcd1-23, Mcd1-43, Mcd1-12, Mcd2-12, Mcd3-19, Mcd4-32, Mcd4-50, Mcd4-11, Mcd4-12, Mcd4-28, Mcd7-42, Mcd8-45, Mcd8-10, Mcd10-9, Mcd10-44, Mcd10-6, Mcd10-4, Mcd10-14, Mcd11-9, Mcd11-31, Mcd11-18, Mcd12-30, Mcd12-5, Mcd13-34, Mcd14-20, Mcd15-38, Mcd15-8, Mcd15-15, Mcd15-27, Mcd16-4* and *Mcd16-50*) exhibited average coefficient of infection(ACI) values between 0 and 20. Therefore, these genotypes are considered to have slow rusting resistance.

On the other hand, 133 durum wheat varieties and landraces had ACI value of 21 to 40 designated as having moderate levels of slow rusting resistance. However, the rest 57 durum wheat varieties and landraces including the susceptible checks had ACI values of more than 40. Similarly, [28] and [12] appraised slow rusting resistance to wheat leaf rust with coefficient of infection and reported the presence of different adult plant resistance conferring genes in wheat cultivars.

3.4. Area under disease progress curve (AUDPC)

Disease progress curve is a better indicator of disease expression over time [29]. Therefore, selection of cultivars having lower AUDPC value is acceptable for practical purposes. Based on the AUDPC value the tested wheat cultivars categorized in to three distinct groups for slow rusting resistance. Cultivars exhibited AUDPC value up to 30% of the check were grouped as having high level of partial resistance, while those cultivars having AUDPC values up to 70% of the check were grouped as moderately resistance cultivars and cultivars having above 70% of the check were grouped as susceptible cultivars [27].

In this study, five wheat cultivars (*Megenagna, Selam, Mossobo, Bekelcha,* and *Utuba*) and four landraces (*Mcd3-19, Mcd4-32, Mcd4-12,* and *Mcd7-42*) showed rAUDPC values lower than 30. Of these *Megenagna, Mcd3-19, Mcd4-12,* and *Mcd7-42* showed moderately susceptible (MS) response and the rest showed moderately resistance (MR) responses. According to [30, 31 and 32], genotypes that had MS infection type and low AUDPC might carry genes conferring durable resistance. These types of genotypes first shown rust infection characterized by chlorotic and necrotic lesions; subsequently the disease progression remained slower and highly retarded. Such partially resistant cultivars could highly delay evolution of new virulent races of the pathogen because multiple point mutations are extremely rare in such circumstance [33 and 34].

On the other hand, *Selam, Mossobo, Bekelcha, Utuba,* and *Mcd4-32* showed MR responses. The moderately resistance on this cultivars could be because of hypersensitive responses; such type of resistance often breaks down due to the development of new races of the pathogen. Suitable breeding strategies like direct transfer of these resistance genes through backcrosses used to develop resistance varieties in durum wheat breeding program.

From the tested durum wheat genotypes, 152 displayed relative AUDPC values of 70% when compared to the susceptible checks (100%). Of these, 24 were released cultivars while 128 were durum landraces and these genotypes are considered possessing moderate level of slow rusting resistance. The rest 74 genotypes showed rAUDPC value above 70% of the checks and were

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considered as susceptible. Other researchers have also reported variation in AUDPC among different wheat cultivars and genotypes with lower AUDPC values considered to have slow rusting resistance to leaf rust [12 and 35].

3.5. Disease progress rate

Slow rusting resistance is characterized by a reduced rate of epidemic development despite a compatible host pathogen interaction [22 and 19].Therefore, cultivars having lower disease progress rate are acceptable for practical purpose.

The maximum disease progress rate observed on the cultivar *Malefia* while, the minimum were on cultivar *Mossobo* and Megenagna. Cultivars *Megenagna, Selam, Mossobo, Bekelcha, Utuba, and Mcd4-32* showed low disease progress rate per unit time. Disease progress rate of few cultivars (*Malefia, Leliso, Mcd5-50* and *Mcd3-25*) were more than the susceptible cultivars, due to the fact that disease scoring was started when disease severity was already observed in certain level on the susceptible checks. Hence, the actual infection rate for susceptible checks may even be more but minimal green tissue was available.

Gompertz model was used to describing the rate of leaf rust infection. The coefficient of determination (R^2) was higher for Gompertz model. Based on Gompertz model the regression equation used to describe the rate of leaf rust progress was not significant for all cultivars, except for susceptible cultivars apparently because of low disease development per unit day on slow rusting cultivars. The coefficient of determination was low for each slow rusting cultivar. However, in most susceptible cultivars the disease progress rate was significance (0.05%). Generally, variation in wheat leaf rust disease progress rate due to the resistance level of the cultivars was clearly observed. Wheat leaf rust was increasing more rapidly on susceptible cultivars than slow rusting cultivars.

3.6. Correlations of between slow rusting resistance parameters of leaf rust

Table 3: Correlations among leaf rust resistance parameters in durum wheat genotypes

Parameters	TRS	ACI	AUDPC	DPR
TRS				
ACI	0.84**			
AUDPC	0.83**	0.97**		
DPR	0.47**	0.49**	0.50**	

**** =**significant level at P<0.01, TRS=Terminal rust severity, ACI= Average coefficient of infection, AUDPC= Area under disease progress curve, DPR= Disease progress rate.

A positive and strong correlation of TRS with AUDPC r = 0.83 (p<0.01) and ACI r = 0.84 (p<0.01) was found, while TRS with DPR showed weak positive correlation r= 0.47 (P<0.01). ACI with AUDPC also showed strong positive correlation r= 0.97 (P<0.01), but ACI with DPR showed weak positive correlation r= 0.49 (P<0.01). AUDPC and DPR also showed weak positive correlation r= 0.50 (P<0.01).

A strong positive correlation of all slow rusting parameters except Disease progress rate agreed with the result of [33, 35, and 36]. Although positive correlations were obtained between Disease progress rate and other slow rusting parameters, the relationship between the variables were weak, this indicates that the rate of infection reduce as epidemic progressed because less healthy tissue was available for additional infection [37].

Since TRS, ACI and AUDPC had strong positive correlations; selection of cultivars having terminal rust severity less than 30%, ACI between 0 to 20 and AUDPC less than 30% is normally accepted for practical purpose [27, 35, and 25]. Feasibility of measuring slow rusting resistance under field condition preferably by low terminal rust severity and infection coefficient has been reported by [25]. [38] also reported field selection for the slow rusting resistant preferably by low AUDPC value.

Accordingly, durum wheat cultivars Namely; *Megenagna, Selam, Mossobo, Bekelcha, Utuba,Mcd4-32, Mcd4-12* and *Mcd7-42* were identified for resistance breeding with slow rusting resistance characteristics; TRS 0-30% with MR and MS response, ACI 0-20, AUDPC less than 30% .

Cultivars *Boohai, Bichena, Quamy, Tate, Denbi, Worer, Toltu, Mukuye, Mangudo*and other 119 landraces had TRS 31 to 50%, ACI values ranging from 21 to 40 and rAUDPC between 31 and 70% and were regarded as moderately slow rusting resistance cultivars. However, the rest 99-durum wheat genotypes had no slow rusting resistance.

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The slow rusting and moderately slow rusting durum wheat genotypes identified in this study are expected to possess genes for varying degrees of slow rusting and could be useful for further exploitation in durum wheat improvement programs. [39] have also reported that genotypes, which have high and moderate slow rusting resistance could have durable resistance controlled by more than one gene that can serve as good parents for resistance breeding.

In this study, two hundred durum landraces evaluated for adult plant resistance and only eighty-eight landraces found moderately resistance, but all others found susceptible to the prevailed leaf rust isolates; such highly susceptibility of Ethiopian durum landraces for leaf rust also previously reported [40].

4. CONCLUSIONS

Evaluated durum wheat varieties and landraces showed variations in the level of Adult plant resistance, implying that there could be some diversity in the number of genes involved and on the size of their effect in conferring those types of resistance.

High yielding cultivars of durum wheat that is nearly immune to leaf rust could be developed by accumulating four to five slow rusting resistance genes through intercrossing parents that showed intermediate disease levels. Several adult plant resistances of durum cultivars identified in this study are being utilized for durable resistance in Ethiopian durum wheat improvement program. However, furthest testing for stability over years and locations for leaf rust along with other desirable characters required.

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