International Journal of Plant Research 2020, 10(3): 61-66
DOI: 10.5923/j.plant.20201003.03

Evaluation of Durum Wheat (*Triticum turgidum*) Varieties Against Stem Rust (*Puccinia graminis* f.sp. *tritici*) in Selected Districts of Southern Ethiopia

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Abstract Stem rust (*Puccinia graminis* f.sp. *tritici*) is a major disease of wheat that occurs more in the main wheat growing regions of Ethiopia. The highland of Ethiopia is considered as a hot spot for the development of stem rust diversity. The objective of this study was to evaluate durum wheat varieties to stem rust using 12 varieties under rain fed conditions. The durum wheat varieties were evaluated for wheat stem rust in Dalocha and Mareko districts for two cropping seasons (2016 and 2018). The varieties were planted in three replications using randomized complete block design (RCBD). Combined analysis of variance revealed existence of significant difference ($p \leq 0.05$) in disease parameters and crop performance among varieties. However, differences among the durum wheat varieties were non-significant for some other plant parameters. All durum wheat varieties showed variable response to stem rust and no variety was found completely resistant to stem rust. The varieties Bekelcha, Dire and Yerer exhibited the lowest disease severity of 26.7%, 34.8% and 41.7%, respectively. Compared to other durum wheat varieties, Bekelcha (28.3%), Yerer (30.4%), Dire (32.5%) and Denbi (37.9%) scored lowest stem rust incidence. The result of statistical analysis for yield attributing characters showed significant variations for thousand kernel weight and grain yield. There was highly significant negative correlation between disease incidence and severity to that of grain yield with correlation coefficient ranging from r= -0.709** to r= -0.768**. However, there was highly significantly positive correlation r=0.925** between terminal rust severity and incidence. The combined data analysis across locations and over the years indicated that durum wheat variety Bekelcha, Dire and Yerer performed better grain yield than the other varieties evaluated on the experiment. Thus, from evaluated durum wheat varieties Bekelch and Dire had adequate level of resistance and recommended as best management options against stem rust. The current result demonstrates the need for effective stem rust management to improve the grain yield of durum wheat in Ethiopia.

Keywords Durum wheat, Grain yield, Incidence, Severity, Stem rust

1. Introduction

Wheat (*Triticum spp*.) is the second major food crop of the world in its importance next to rice. Wheat is one of the most important and significant cereal staple food crops in the world, both in terms of food production and for providing the total amount of food calories and protein in the human diet [1]. It is the largest cultivated crop with a 22% of the total arable land in the world [2]. Ethiopia is the first and largest wheat producer in sub-Saharan Africa [3]. It is a traditional staple food crop, cultivated by 4.2 million households on 1.7 million ha of land under rain-fed conditions; and 4.6 million tons of wheat production [4]. Wheat is subdivided into a number of species that are classified according to the number of chromosome pairs they contain. The most common species of wheat grown are *Triticum aestivum* L. (bread wheat) and *Triticum turgidum var. durum* L. (durum wheat).

Durum wheat (*Triticum turgidum*) is the predominant tetraploid species grown in Ethiopia. Durum wheat belongs to family Poaceae tribe Hordeae. It is consumed in many forms like bread, Pasta, cakes, biscuits, bakery products, and many confectionery products. Now a day there is increasing demand of durum wheat varieties used in bakery purpose, but the farmers are unaware about the durum wheat and its importance. Pasta is the most common product of the durum wheat which is considered as one of the most important food staples in most part of the world.

In Ethiopia occupies close to 520,000 ha of arable land was covered with durum wheat [5]. It is traditionally grown on the heavy black clay soils (Vertisols) of the highlands at altitudes ranging between 1800 and 2800 meters above sea level (m.a.s.l). In the highlands of Ethiopia the distribution of rainfall is bimodal and may vary from 600 to more than 1200

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Published online at http://journal.sapub.org/plant

mm per annum [6]. The majority of cultivated durum wheat varieties (close to 85%) are landraces [7].

Despite the large area under wheat in Ethiopia the national average yield is still 2.78 t/ha, which is by far less than potential yields of 8 to 10 t/ha [4]. The average yield of durum wheat is even less 1.3 t/ha. The low productivity is attributed to multi-faced abiotic and biotic such as cultivation of unimproved low yielding varieties; low and uneven distribution of rainfall, poor agronomic practices, insect pests and serious diseases like rusts [8]. Among biotic factors, rust diseases play a significant role in Ethiopia up to 75% wheat yield loss [9]. Over 30 fungal wheat diseases are identified in Ethiopia. Wheat stem rust caused by *Puccinia graminis* f.sp. *tritici* is one of the major constraints in most of the wheat growing areas of the country; causing yield losses of up to 100% during epidemic years [10].

There are several control measures for controlling wheat rust such as chemical application (as fungicides spray), cultural practices (crop rotation, seed dressing and removing disease debris) and use of resistant cultivars [11]. Genetic resistance is considered the most reliable and environmental friendly approaches for controlling stem rust. For that reason, diverse resistant varieties should be developed to provide durable and long term resistance against stem rust. With the evolution of new races of rust pathogen, the resistance of present durum wheat cultivars is at high risk so there is a strong need to screen and know the level of resistance of current cultivars against stem rust. Silte and Gurage zone are among the wheat producers in the region which is highly exposed to wheat stem rust damage [12]. Hence, this study was planned to evaluate durum wheat varieties against stem rust under rain fed conditions.

2. Materials and Methods

Description of the Experimental Areas

The field experiments were undertaken by Werabe Agricultural Research Center (WARC) in 2016 and 2018 cropping season under rain fed conditions. The study was carried out at Dalocha and Mareko district of Southern Nation Nationalities and peoples Regional State (SNNPRS). Both experimental sites are situated under major wheat growing areas of Southern Region characterized by *Woin-adega* Agro-ecologies. Dalocha site is specifically located at 07°83'62"N, 38°22'12"E and with elevation of 1956 m.a.s.l. The mean annual rain fall of the area is 982 mm and with average temperature of 26°C. Mareko site is located at 08°05'67"N, 38°50'81"E and with elevation of 1834 m.a.s.l. The mean annual rain fall of the area is 854.4mm and with average temperature of 25°C. Both locations are stem rust prone areas and characterized by bimodal rainfall, the short rainy season extending from March to May and the main rainy season from June to September.

Experimental Design and Treatments

Twelve durum wheat varieties (Ude, Mesobo, Odda, Bekelcha, Assasa, Tate, Denbi, Mukuye, Yerer, Mangudo, Toltu and Dire) were evaluated for their response to stem rust in 2016 and 2018 main cropping season. These durum wheat varieties were released from Debre Zeit Agricultural Research Centre (DARC). Stem rust was allowed to develop naturally in each variety without any artificial inoculation. The experimental design was randomized complete block design (RCBD) with three replicated plots. Each plot was arranged with distance of 1m between block and 0.5m between plots. Six row plot of 1.2m x 2.5m and 0.2m spacing were used. Sowing was done by hand drilling at a seed rate of 125 kg ha-^{1} at appropriate planting time for each location. Experimental plots were fertilized with blended fertilizer NPS used with composition of 19%N-38%P_2O_5-+ 7%S at the rate of 121 kg ha-^{1} just at planting and Urea (N46%) at a rate of 100 kg/ha with split application. Weeding and other agronomic practices were carried out as per available recommendations for respective locations.

Data collected

Data on grain yield and yield component agronomic and disease parameters were recorded from the central four rows of each plot. The average number of effective tiller per plant was taken from four central row of each plot. Plant height (PH) (cm) was taken at full maturity from five randomly selected plants of the central rows and measured from the ground level to the top of the plant and average was used for statistical analysis. Grain yield (GY) data was recorded from clean and dried samples and plot yields were converted to kilogram per hectare. Thousands kernel weight (TKW) were counted by carefully by adjusting to 12.5% moisture content and weighing them on electronic balance.

Disease incidence

Disease incidences were recorded in percentage from infected plant on each plot from total number of pant examined.

$$\text{Diseases Incidenc} = \frac{\text{Numberof diseased plants}}{\text{Total number of plants examined}} * 100$$

Diseases severity

Terminal rust severity was recorded at maturity stage of the crop the using Modified-Cobb scale where 0% = immune and 100% = completely susceptible in combination with field reaction [13]. Five randomly selected plants were tagged with colored thread before the disease appearance. Crop growth stage was determined based on the decimalized key developed by [14]. Disease parameters were calculated using the formula described blow.

$$\text{Disease severity} = \left(\frac{\text{Area of plant tissue affected}}{\text{Total area of plant tissue examined}}\right) * 100$$

Reaction Type

The reaction type was recorded based on the original scales proposed by [15] for stem rust and other rust diseases in field evaluation. Five rust reaction types were used for durum wheat varieties. These are Immune (I- no visible symptoms), Resistant (R- Necrotic areas with or without minute uredia, Moderately resistant (MR- Small uredia present surrounded by necrotic area), Moderately susceptible

(MS- Medium uredia with no necrosis but with some possible distinct chlorosis), Susceptible (S- Large uredia and little or no chlorosis present).

Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS computer package version 9.0 (SAS Institute, 2002). Means were separated by using least significant difference (LSD) ($p<0.05$) value. Combined analyses of variance were performed using data across locations and years. Data on disease parameters yield and yield components were correlated using the Proc-Corr Pearson's correlation of SAS computer software package.

3. Results and Discussion

Due to homogeneity of data over cropping years, combined analysis was done for the disease parameters and yield and yield components. The results from the present study revealed that durum wheat varieties depicted different responses to stem rust and other agronomic traits at Dalocha and Mareko districts. Combined analysis of variances indicated that except for number of tillers and plant height, durum wheat varieties showed significant differences for thousand kernel weight and grain yield.

Diseases Reaction

Among the 12 tested durum wheat varieties, three Mukye, Mesebo and Toltu showed susceptible reaction to stem rust. Tate, Mangudo, Ude, Odda and Assasa varieties exhibited moderately susceptible (MS - medium sized pustules) reaction to stem rust. Denbi, Deri and Yerer had moderately resistant (MR - small pustules surrounded by necrotic areas) response. This means that the level of infection is kept much below threshold level to cause yield loss due to stem rusts. On the other hand the variety Bekelcha showed only relatively resistant reaction from all varieties evaluated on the trial within two consecutive seasons at both locations under field condition. The ability of variety to resist the disease might be containing resistant Sr gene against stem rust. The results of this study also support the fact that durum wheat cultivars and the local landrace could be valuable sources of resistance to the stem rust in the area. Majority of cultivars in present experiment were found moderately susceptible (MS) to stem rust. This shows the pathogenic pressure and possible evolution of new races of *Puccinia graminis* in experimental region which highlighted an urgent need for evolutionary and pathogenicity study of wheat stem rust pathogen in this area.

Diseases Incidence

Durum wheat varieties showed significant differences for percentage of disease incidence. As indicated in Table 1 the maximum diseases incidence of 61.7%, 59.6% and 58.75% were recorded from susceptible varieties of Mukye, Toltu and Mesebo respectively. The highest disease incidence of 55.2%, 54.1%, 52.1%, 50.4%, 42.5%, were obtained from the moderately susceptible varieties of Tate, Mangudo, Ude, Odda and Assasa respectively. Bekelcha (28.3%), Yerer (30.4%), Dire (32.5%) and Denbi (37.9%) scored lowest stem rust incidence as compared to other varieties. Disease incidence on the susceptible variety was significantly different from the resistant and moderately resistant varieties at both locations. However, there was no significant difference between the susceptible and moderately susceptible varieties. The variation in disease incidence among the varieties might be due to the resistance level of the varieties. In general, stem rust recorded at both cropping season and locations and this indicated that in all season the stem rust occurred at epidemic level and good opportunity to see the disease states of our durum verities.

Disease Severity

The finding of the present study revealed that terminal stem rust severity was significantly affected ($P<0.05$) by wheat varieties Table 1. Disease severity varied with the resistance level of the varieties and the prevailing environmental factors.

The maximum terminal rust severities (TRS) of 68.8%, 67.2% and 66.1% were recorded from on susceptible (Mukye, Mesebo and Toltu) varieties, respectively. On the other hand the highest TRS of 62.9%, 64.6%, 64.4%, 61.1% and 63.5% were obtained on moderately susceptible (Tate, Mangudo, Ude, Odda, Assasa) varieties respectively. The lowest TRS 18.4% was recorded from relatively resistant variety Bekelcha. The stem rust disease severity ranged from 18.4 to 68.7%. According to [16] 0 to 20% indicates low disease severity, 21 to 40% is medium while greater than 41% is considered as high.

Disease severity is a good indicator of plant resistance under field condition. It is directly related with the yield loss. Onset of stem rust was relatively late in relation to the crop growth stage at both locations. The disease appeared at booting stage at Mareko and at heading stage at Dalocha in both seasons. This is due to variation in the environmental factors for epidemic development of the disease. The highly susceptible variety (Mukye, Mesebo and Toltu) showed significant difference in stem rust severity as compared to the other varieties during all the assessment time.

The present study indicated that stem rust epidemic development on all leaves and flag leaves was different for different varieties at both locations. This is explained by changes in environmental variables and aggressiveness of the pathogen over locations. Changes in environmental factors also modify host morphology, physiology and resistance. This is in agreement with [17] who reported that climate change modifies host physiology and resistance, and alter the stages and rates of the development of pathogens.

The variability in both severity and infection response of cultivars at both testing locations clearly shows that the stem rust pathogen populations have differences in their virulence. Disease severity of stem rust was higher on susceptible and moderately susceptible varieties which resulted substantial yield losses. The result of present study was line with the finding of [18] who reported that yield losses increased proportionately with the increase in severity of the disease.

Considerable variation was observed among tested durum wheat varieties and had broad resistance spectrum. This might be associated with the fact that most of the durum wheat cultivars were developed from local landraces, which have co-evolved with indigenous pathogen populations. The result of research finding was also in agreement with the previous report, which stated that the Ethiopian cultivated tetraploid wheat accessions are resistant or moderately resistant to stem rust and the landraces are found to be a potential source of resistance to stem rust [19].

Overall terminal rust severity was higher in both cropping season. This might be due to conducive environmental conditions and the evolvement of new pathotype. Similarly [20] reported that weather factors influence occurrence and severity of stripe rust epidemics on winter wheat. Efforts should be made towards accelerated variety replacement with other resistant and high yielding ones before the virulent stem rust put them out of production. This is because varieties that are resistant to stem rust in one year or one location may be susceptible in another year or location depending upon the virulence of the pathogen.

Tillerig

The finding of the present study revealed that durum wheat verities did not showed significant difference in terms of tillering at both locations Table 1. The highest tillering per plant 4.9 and the lowest tillerig per plant 4.0 was obtained from moderately susceptible variety of Mangudo and Odda, respectively. Mangudo had a great number of tillering capacity and preferred by most farmers in the area but they did not have adequate level of resistance against the stem rust disease.

Plant Height

In this field experiment, the tallest plant 75.5cm and the shortest plant 61.6cm were recorded from Assasa and Mangudo varieties, respectively Table 1. The difference in plant height did not showed significant difference in all tested durum wheat varieties due to disease pressure because variation among the varieties was based on genetic background rather than stem rust disease. These results of the research finding are in agreements with the repot of [21] who observed non significant response.

Thousand Kernel Weight

There was significant ($P<0.05$) difference on thousand kernel weight among tested durum wheat the varieties. Thousand kernel weight (TKW) at both season ranged from 32.7 to 39.4 from susceptible to resistant varieties, respectively. The maximum TKW of 39.4 and 37.5 from moderately resistant and 39.0 and 37.5 from moderately susceptible varieties were obtained on the trial. The lowest TKW of 32.7 was recorded from susceptible variety of Toltu at both locations. The stem rust reduced the TKW of durum wheat by shriveling of wheat kernels on susceptible varieties.

TKW measure was the best indicator to estimate the effect of stem rust on grain yield of durum wheat. Thousand kernel weights is the integral parameter of overall yield and differ from genotype to genotype. In present field experiment, thousand kernel weights showed significant variation among the durum wheat varieties. TKW were variable according to the cultivar response and significantly affected by stem rust infection at both locations. The disease pressure was greater at flowering and milk stage of the crop development and resulted significant impact on grain feeling process of few susceptible varieties. Infection of wheat stem and leaf sheaths by wheat stem rust affects the transport of assimilates to the developing kernel and results in shriveled kernel [22,23].

Table 1. Effect of stem rust on 12 durum wheat varieties

Variety	INC (%)	TRS (%)	NT	PH	TKW	GY
Assasa	52.1^{a}	63.5^{ab}	4.5^{ab}	75.5^{a}	37.5^{a-c}	3624^{ab}
Odda	42.5^{bc}	61.1^{b}	4.0^{b}	71.2^{ab}	34.7^{cd}	3434^{ab}
Toltu	59.6^{a}	66.1^{ab}	4.5^{ab}	71.1^{ab}	32.7^{d}	2995^{bc}
Mukye	61.7^{a}	68.8^{a}	4.2^{b}	70.8^{ab}	35.3^{b-d}	3418^{ab}
Mesebo	58.7^{a}	67.2^{ab}	4.3^{ab}	69.9^{ab}	36.4^{a-d}	3183^{b}
Denbi	37.9^{cd}	39.8^{c}	4.1^{b}	69.0^{b}	37.7^{a-c}	3766^{ab}
Yerer	30.4^{de}	41.8^{c}	4.2^{b}	67.5^{bc}	39.4^{a}	4038^{a}
Udie	50.4^{ab}	64.4^{ab}	4.4^{ab}	63.8^{cd}	39.0^{ab}	3195^{b}
Dire	32.5^{de}	34.8^{c}	4.4^{ab}	63.3_{cd}	34.6^{cd}	4100.6^{a}
Bekelcha	28.3^{e}	21.6^{d}	4.5^{ab}	63.2^{cd}	35.9^{a-d}	4072.3^{a}
Tate	55.2^{ab}	62.9^{ab}	4.2_{b}	63.2^{cd}	33.9^{cd}	3816.7^{ab}
Mangudo	54.2^{ab}	64.6^{ab}	4.9^{a}	61.6^{d}	35.5^{a-d}	3958^{a}
CV (%)	20.87	13.08	18.55	8.85	12.88	25.1
$LSD_{0.05}$	7.6	6.63	Ns	4.866	3.7	223

PH (cm): plant height, NT: number of tiller, SRS (%): stem rust severity, TKW (g): thousand kernel weight in, GY (kg): grain yield.

Table 2. Pearson's correlations among six traits

	INC	TRS	NT	PH	TKW	GY
INC	1.0000					
TRS	0.925**	1.0000				
NT	0.175ns	0.058ns	1.0000			
PH	- 0.194ns	-0.284ns	-0.362*	1.0000		
TKW	-0.348*	-0.384*	0.175ns	0.038ns	1.0000	
GY	-0.709**	-0.768**	0.325*	-0.519**	0.489**	1.0000

*** refers to highly significant at= 0.01, * refers to significant at= 0.05, ns: refers not significant, INC: Incidence, TRS: Terminal rust severity, PH: plant height, NT: number of tiller, TKW: thousand kernel weight, GY: grain yield*

Grain Yield

The finding of the present study revealed that significant variation was noticed ($p<0.05$) for the grain yield among the durum wheat varieties. The maximum grain yield of 4072kgha-^{1}, 4100.6kgha-^{1} 4038kgha-^{1}, was obtained from Bekelcha, Dire and Yere varieties respectively. Resistant (Bekelcha) and moderately resistant (Dire and Yerer) had better effect in reducing stem rust epidemics, increased grain yield and yield components, and showed higher economic benefits over other durum wheat varieties. From the result of research finding it is possible to reduce yield loss due to stem rust using relatively resistant varieties like Bekelcha. The result of research finding was similar with the finding of [24] who reported that host resistance is the most economical and safest method for controlling the disease.

The highest grain yield of 3816.7kgha-^{1}, 3959kgha-^{1}, 3159kgha-^{1}, 3434kgha-^{1}, and 3624kgha-^{1} were obtained from the moderately susceptible varieties of Tate, Mangudo, Ude, Odda and Assasa, respectively. The grain yield of 3418kgha-^{1}, 3183kgha-^{1} and 2995kgha-^{1} were obtained from susceptible varieties of Mukye, Mesebo, and Toltu respectively. Majority of varieties showed low grain yield which represents that susceptibility to biological stress may be the cause of lower yield in these varieties. Similarly [25] reported that stem rust reduced yield irrespective of the type and level of resistance possessed by the varieties. The effect of stem rust infection on grain yield losses of wheat genotypes possibly in consequence of the effect on the photosynthetic area of the top three leaves especially flag leaf, which shares with its sheath by about 75% in determining the grain weight. Except the relatively resistant variety Bekelch the rest of variety should be supported with fungicide application because reinfection of disease was occurred on them and better economic benefit could be obtained.

Yield is the most desirable and important parameter of crop plant. Grain yield vary from genotype to genotype due to genetic variation of crop plant. Grain yield depends on genetic potential of a genotype against biotic and a-biotic stresses and overall performance of individual plant. The present study also showed that varieties with maximum disease severity exhibited maximum yield losses. These were happened on moderately susceptible varieties of Mangudo and Tate. It was also evident that susceptible genotypes suffered more yield losses than those having moderately resistant to resistant reactions to stem rust.

Correlations

Analysis of the data indicated a negative correlation between the disease incidence and terminal rust severity with grain yield and thousand kernel weights at both locations Table 2. The grain yield and terminal rust severity was associated with negative and highly correlated at (r= -0.768**). This implies that when there is an increase in disease severity there was a decrease in yield parameters and vice versa. This might be due to favorable environmental conditions for the development of stem rust during the main season. The result of research finding was in agreement with the finding of [26] who reported a significant correlation between mean disease severity and percent loss in grain yield and thousand kernels.

4. Summary and Conclusions

Durum wheat (*Triticum turgidum*) is among the most important cereal crops in Ethiopia. However, the production is constrained by many biotic and abiotic factors, and socio-economic constraints. Among these stem rust disease is becoming a leading of bottle neck for the production of durum wheat in Ethiopia. Evaluation of durum wheat varieties for their resistances is very important in integrated stem rust management. Most of the tested bread wheat varieties do not have adequate level resistance for stem rust disease. Stem rust disease resulted in significant reduction in thousand kernel weight, grain yield during both cropping season. From the evaluated durum wheat varieties against stem rust in hot spot experimental location, it is concluded that durum wheat varieties Bekalcha was relatively resistant and Dire and Yere were moderately resistant to stem rust and produced sub optimal yield while Mukye, Mesebo, Toltu, were susceptible to stem rust and performed poor in this experiment. Thus from evaluated durum wheat varieties Bekelcha and Dire are the recommended varieties to our farmer in order to decrease the yield loss due to stem rust for the coming cropping season. These two varieties can serve as important sources of resistance to the stem rust races prevailing in Ethiopia and they should be included in the crossing blocks of the regional wheat breeding research project. Therefore, regular assessment and evaluation of durum wheat varieties against stem rust to will be mandatory to generate relevant information in Silte and Gurage zones. Moreover, there should be an urgent need for developing new durum wheat varieties resistant to the stem rust disease to secure wheat production.

ACKNOWLEDGEMENTS

Without the support of some individuals and institutions the successful completion of this experiment would have not been realized. Southern Agricultural Research Institute, (SARI) and Werabe Agricultural Research Center (WARC) are duly acknowledged for fully funding this work. We would like to offer a great thanks to all crop research teams of Worabe Agricultural Research Center played their unreserved role, I would like to say thank you all.

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