American Journal of Life Sciences
2021; 9(4): 60-66
http://www.sciencepublishinggroup.com/j/ajls
doi: 10.11648/j.ajls.20210904.11
ISSN: 2328-5702 (Print); ISSN: 2328-5737 (Online)

Evaluation of Ethiopian Bread Wheat Cultivars for Slow Rusting Resistance to Yellow Rust (*Puccinia striiformis* f.s Tritici)

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To cite this article:
Alemu Ayele Zerihun. Evaluation of Ethiopian Bread Wheat Cultivars for Slow Rusting Resistance to Yellow Rust (*Puccinia striiformis* f.s Tritici). *American Journal of Life Sciences*. Vol. 9, No. 4, 2021, pp. 60-66. doi: 10.11648/j.ajls.20210904.11

Received: May 18, 2021; **Accepted**: July 5, 2021; **Published**: July 13, 2021

Abstract: Wheat stripe rust (*Puccinia striiformis* f.s. *tritici*) is the greatest vicious rust disease in wheat-growing areas of Ethiopia. The cultivating of cultivars with polygenic gene resistance is the most efficient way of monitoring the disease. Field experiments were carried out at Kulumsa Agricultural Research Center main station and, Meraro and Bekoji substations of Ethiopia during 2019 to 2020 main cropping seasons to disclose variability for field based adult plant resistance to yellow rust among 25 newly developed bread wheat cultivars advanced in Ethiopia. Features used as criteria to identify adult plant resistance comprised response of wheat cultivars to yellow rust, Coefficient of infection (CI), relative final rust severity (FRS) and area under disease progress curve (rAUDPC) were found to be reliable to evaluate slow rusting in the cultivars. The outcomes shown that wheat cultivar only Balcha had low disease severity (< 30%) with MRMS reaction, lower rAUDPC values (>30%) and CI (< 20) and were recognized to have good level of adult plant resistance while eighty eight percent of the tested cultivars exhibited susceptible and grouped under low slow rusting resistance with high disease pressure over all three locations. Cultivars Dashen, Daka, Wane and Sanate had moderate values for slow rusting parameters and were recognized as having moderate level of slow rusting. The slow rusting cultivars identified from the present work can be used for extra management in wheat development programs.

Keywords: Yellow Rust, Bread Wheat, Cultivar, Severity, Low Rusting

1. Introduction

Wheat yellow rust, caused by *Puccinia striiformis* is one of the most prevalent and damaging diseases of wheat globally [1], particularly in cool climates, present in almost all the wheat growing areas of the world and a formidable threat to global wheat production [2-4]. It is the major bottleneck in major wheat producing area of Ethiopia especially Arsi and Bale regions are the known hotspot areas for the epidemics of wheat stripe rust [5, 6]. The main reasons for periodic outbreaks of yellow rust disease in Ethiopia is the scarce information on the genetic variation of host-pathogen interactions and unreliability of current sources of resistance to the prevailing race population [7].

Wheat yellow rust is the most prevalent type of rust, which causes yield losses up to 91.5 to 96.7% on susceptible cultivars and 48.7 to 57.5% on moderately susceptible cultivars [8]. The best alternative to reduce losses from such a disease would be to use resistant cultivars. Cultivation of resistant varieties of wheat against stripe rust is effective, feasible and environmentally friendly method of disease control [9]. However, cultivars with race-specific genes usually remain effective for only a few years because the pathogen changes to virulent on individual resistant genes and some plants are also resistant to stripe rust at the adult plant stage (boot stage); such plants have high temperature adult plant (HTAP) resistance.

Bread wheat cultivars relying on single gene resistance having with major gene effect often has low effectiveness to yellow rust disease resistance and breaks its resistance within a few years by forming instability of selection for aggressive yellow rust races [10, 11]. Because of instability of resistance in cultivars that have only a single major gene effect for resistance, current breeding programs have concentrated on

rising cultivars with slow rusting. Slow rusting resistance is a type of resistance that is characterized by a reduced rate of epidemic development despite compatible host pathogen interaction [12, 13]. It is polygenic and effective against a broad range of yellow rust races [14-16]. Slow rusting resistance is described by a slow epidemic build up regardless of a high infection type representing a compatible host-pathogen relationship [17, 13].

Even though numerous findings have been supported out to evaluate yellow rust resistance in different wheat cultivars in Ethiopia, many of them were based on vertical resistance. Thus, the present study was planned to evaluate the levels of slow rusting resistance in some currently cultivated commercial bread wheat cultivars to yellow rust under field conditions.

2. Materials and Methods

To evaluate 25 released bread wheat cultivars (Table 1) for their slow rusting resistance to yellow rust. Field experiments were conducted during 2019 to 2020 main cropping season (June to November) at Kulumsa Agricultural Center main station, and Bekoji and Meraro sub stations. Wheat cultivar Morocco which is universal susceptible variety considered to lack resistance genes to the yellow rust pathogen was used as a comparative control in the experiments. The experiments were laid out in randomized complete block design (RCBD) with four replications. Each plot consisted of two rows with a size of 1 m × 40 cm and a spacing of 1 m between blocks and 0.2 m between plots. To ensure uniform spread of inoculum and for sufficient disease development during the trial periods susceptible wheat cultivar Morocco was planted a week earlier around the experimental areas. Artificial inoculation was not carried out due to high yellow rust disease pressure and highly hot spotted experimental sites naturally. The recommended fertilizer application, insect and weed control methods were undertaken as per recommendations.

Table 1. *Description of the wheat cultivars used for evaluation of slow rusting resistance.*

S/NO	Cultivars	Year of release	Source	S/NO	Cultivars	Year of release	Source
1	Digalu	2004	KARC/EIAR	14	Danda'a	2010	KARC/EIAR
2	Kubsa	1995	KARC/EIAR	15	Lemmu	2016	KARC/EIAR
3	PBW343	1995	KARC/EIAR	16	Alidoro	2007	KARC/EIAR
4	Dashen	1984	Adet	17	Huluka	2012	KARC/EIAR
5	Lakech	1967	KARC/EIAR	18	Hoggana	2012	KARC/EIAR
6	Sanate	2014	KARC/EIAR	19	Madawalabu	2000	Sinana/OARI
7	Isreal	-	Adapted	20	Hidasie	2012	KARC/EIAR
8	Enkoy	1974	Adapted	21	Kingbird	2015	KARC/EIAR
9	Pavon 76	1982	KARC/EIAR	22	Wane	2016	KARC/EIAR
10	Shorima	2011	KARC/EIAR	23	DAKA	2018	KARC/EIAR
11	Galama	1995	KARC/EIAR	24	Balcha	2018	KARC/EIAR
12	Kakaba	1995	KARC/EIAR	25	Morocco	Susce.c	KARC/EIAR
13	Ogolcho	2013	KARC/EIAR				

KARC, Kulumsa Agricultural Research Center, EIAR-Ethiopian Institute of Agricultural Research, OARI- Oromia Agricultural Research Institute.

2.1. Disease Scoring

Disease Scoring was made three times at Kulumsa and Bekoji, and four times at Meraro experimental stations at fourteen days interval, starting when susceptible spreader rows reached 20% severity according to the Modified Cobb Scale [18].

2.2. Final Rust Severity (FRS)

Disease severity was assessed by estimating the approximate percentage of leaf area affected using modified Cobb scale on all tillers of plot based entries of two rows. Disease severity was taken at fourteen days interval starting when yellow rust levels on Morocco reached 20% severity. The host plant response to infection was scored according to [19]. Final rust severity (FRS) was used to classify wheat genotypes into different group such as 1-30 percent as moderately resistant, 31-50 percent as moderately susceptible and 51-90 percent as susceptible.

2.3. Coefficient of Infection (CI)

Coefficient of infection was calculated by multiplying the percentage severity and the constant value assigned to each reaction type [20]. The constant values were considered as no disease=0, Resistant (R) = 0.2, Moderately Resistant (MR) =0.4, Moderately Resistant to Moderately Susceptible (MRMS) =0.6, Moderately Susceptible (MS) =0.8, Moderately Susceptible to Susceptible (MSS) =0.9, Susceptible (S) =1

2.4. AUDPC and rAUDPC Value

Area under disease progress curve: calculated using the CI values from the original rust severity data by using the following formula as suggested by [21].

AUDPC (Area under Disease Progress Curve) and rAUDPC (Relative Area under Disease Progress Curve) values were calculated as [22].

$$AUDPC = \frac{N1(X1 + X2}{2} + \frac{N2(X2 + X3)}{2} + \frac{N3(X3 + X4)}{2}$$

Where, X1, X2, X3 and X4 are rust intensities recorded on first, second, third and fourth recording date and N1 is

interval day between X1 and X2 N2 is interval day between X2 and X3, N3 is interval day between X3 and X4

$$rAUDPC = (\frac{line\ AUDPC}{Susceptible\ AUDPC})100$$

3. Results and Discussion

3.1. Final Rust Severity

There is wide difference in the severities of wheat stripe rust ranging from trace to 90% at all location during the 2019 and 2020 cropping seasons at the Kulumsa Agricultural research center main stations and Meraro and Bekoji substations. The final rust severities and field disease infection of cultivars are presented in the table 2. The tested wheat cultivars based on final rust severities were grouped into three groups slow rusting resistance that are high, intermediate and low levels of adult plant resistance with ranges of 1-30, 31-50 and 51-100% final rust severities values respectively.

At Bekoji experimental station only three cultivars showed disease severities 0 to 30%, three cultivars displayed moderately susceptible 31-50 and twenty cultivars, grouped to low adult plant resistance having high disease (51-100%) severities which were highly susceptible cultivars during 2019. At Meraro five wheat cultivars showed up to 30% disease severities, of which DAKA and Sanate showed MS, Dashen displayed MR, Wane showed MRMS and Pavon 76 showed S type disease reaction. On the other hand four cultivars namely Galema, Alidoro, Hoggana and Wane remained on the second group exhibiting final rust severities 31 to 50% and sixteen cultivars showed low plant resistance with high disease severities exhibiting 51-100% with S type disease reaction, but at Kulumsa three cultivars namely Balcha with MR disease reaction, Dashen and Sanate with nil and MS disease reaction exhibited nine and thirteen cultivars represented intermediate and low adult plant resistance respectively in 2019. Cultivars Sanate, Dashen and Balcha showed moderately resistance at Meraro and moderately susceptible at Bekoji and Kulumsa during 2019 growing season.

At kulumsa five, nine and eleven cultivars showed High (0-30%), intermediate (31-50%) and low (51-100%) slow rusting in disease severity during 2020 cropping season respectively. However the heavy disease pressure at Meraro only one cultivar Balcha displayed high adult plant resistance with MRMS type of disease reaction, two namely DAKA and Wane exhibited 31-50% of disease severities having MS disease reaction and twenty two cultivars exhibiting 88 percent of the planted materials grouped under low plant resistance having high disease severities and S type disease reactions severities during 2020 growing season respectively. Cultivar like Sanate showed immune disease response at kulumsa could be as result of response of hypersensitive resistance often breaks down pathogen of new race development. As suggested by [23] available resistance genes like materials overcome yellow rust virulence in the field and low disease severities led to the compatible host plant reaction. Many researchers like [24-28] marked final yellow rust severity to study adult plant resistance or slow rusting characters of wheat cultivars.

Table 2. *Stripe rust severities and response of commercial cultivars at Kulumsa, Meraro and Bekoji in 2019 cropping season.*

S/NO	Cultivars/Varieties	Kulumsa			Meraro			Bekoji		
		FRS	Drxn	CI	FRS	Drxn	CI	FRS	Drxn	CI
1	Digalu	70	S	70	90	S	90	80	S	80
2	Kubsa	80	S	80	80	S	80	50	S	50
3	PBW343	80	S	80	60	S	60	60	S	60
4	Dashen	10	MS	8	15	MSMR	9	5	MS	4
5	Laketch	80	S	80	90	S	90	50	S	50
6	Sanate	0	0	0	Trace	MS	3.6	10	MS	8
7	Isreal	80	S	80	90	S	90	40	S	40
8	Enkoy	70	S	70	70	S	70	40	S	40
9	Pavon 76	40	S	40	30	S	30	30	S	30
10	Shorima	40	S	40	60	S	60	40	S	40
11	Galema	40	S	40	40	S	40	30	S	30
12	Kakaba	60	S	60	70	S	70	40	S	40
13	Ogolcho	40	S	40	70	S	70	10	S	10
14	Danda'a	60	S	60	60	S	60	40	S	40
15	Lemmu	60	S	60	70	S	70	50	S	50
16	Alidoro	40	S	40	50	S	50	50	S	50
17	Huluka	40	S	40	70	S	70	70	S	70
18	Hoggana	60	S	60	50	S	50	50	S	50
19	Madda Walabu	80	S	80	80	S	80	30	S	30
20	Hidassie	40	S	40	60	S	60	60	S	60
21	Kingbird	70	S	70	70	S	70	40	S	40
22	Wane	40	S	40	50	S	50	20	MSS	18
23	Daka	40	S	40	30	MS	27	30	S	30
24	Balcha	Trace	MR	1.6	5	MRMS	3	5	10MRMS	6
25	Morocco	90	S	90	90	S	90	80	S	80

FRS, final rust severity; CI, Coefficient of Infection; Drxn= disease reaction; MRMS; moderately resistant to moderately susceptible; MS, moderately susceptible, MSS, moderately susceptible to susceptible, S, susceptible.

Table 3. *Stripe rust severities and response of commercial cultivars at Kulumsa, Meraro and Bekoji in 2020 cropping season.*

S/NO	Cultivars/Varieties	Kulumsa			Meraro			Bekoji		
		FRS	Drxn	CI	FRS	Drxn	CI	FRS	Drxn	CI
1	Digalu	90	S	90	90	S	90	90	S	90
2	Kubsa	90	S	90	90	S	90	90	S	90
3	PBW343	70	S	70	90	S	90	90	S	90
4	Dashen	60	S	60	80	S	80	70	S	70
5	Laketch	80	S	80	90	S	90	90	S	90
6	Sanate	50	S	50	70	S	70	70	S	70
7	Isreal	60	S	60	90	S	90	90	S	90
8	Enkoy	50	S	50	80	S	80	60	S	60
9	Pavon 76	40	S	40	80	S	80	60	S	60
10	Shorima	50	S	50	80	S	80	60	S	60
11	Galema	40	S	40	70	S	70	70	S	70
12	Kakaba	60	S	60	90	S	90	60	S	60
13	Ogolcho	90	S	90	90	S	90	90	S	90
14	Danda'a	30	S	30	80	S	80	70	S	70
15	Lemmu	50	S	50	80	S	80	30	S	30
16	Alidoro	30	S	30	60	S	60	40	S	40
17	Huluka	50	S	50	70	S	70	80	S	80
18	Hoggana	40	S	40	70	S	70	80	S	80
19	Madda Walabu	70	S	70	70	S	70	80	S	80
20	Hidassie	60	S	60	60	S	60	50	S	50
21	Kingbird	40	S	40	90	S	90	70	S	70
22	Wane	30	MRMS	18	50	MSS	40	25	MRMS	15
23	Daka	10	MRMS	6	40	MSMR	24	40	MRMS	24
24	Balcha	5	MRMS	3	25	MRMS	15	20	MRMS	12
25	Morocco	90	S	90	90	S	90	90	S	90

FRS, final rust severity; CI, Coefficient of Infection; Drxn= disease reaction; MRMS; moderately resistant to moderately susceptible; MS, moderately susceptible, MSS, moderately susceptible to susceptible, S, susceptible.

Table 4. *Stripe rust AUDPC and rAUDPC values of commercial cultivars at Kulumsa, Meraro and Bekoji in 2019 cropping season.*

S/NO	Cultivars	Kulumsa		Meraro		Bekoji	
		AUDPC	rAUDPC	AUDPC	rAUDPC	AUDPC	rAUDPC
1	Digalu	1237.5	76.39	2980	80.76	950	62.5
2	Kubsa	1305	80.56	3160	85.64	1140	75
3	PBW343	1005	62.04	2460	66.67	1140	75
4	Dashen	82	5.06	615	16.67	142.5	9.38
5	Lakech	1305	80.56	3290	89.16	1140	75
6	Sanate	82	5.06	140	3.79	0	0
7	Isreal	717.5	44.29	3200	86.72	1140	75
8	Enkoy	710	43.83	2630	71.27	760	50
9	Pavon 76	355	21.91	1320	35.77	617.5	40.63
10	Shorima	227	14.01	2060	55.83	475	31.25
11	Galama	317.5	19.6	1580	42.82	475	31.25
12	Kakaba	717.5	44.29	2590	70.19	760	50
13	Ogolcho	205	12.65	2720	73.71	475	31.25
14	Danda'a	302	18.64	2150	58.27	712.5	46.88
15	Lemmu	432	26.67	2500	67.75	760	50
16	Alidoro	224	13.83	1670	45.26	427.5	28.13
17	Huluka	162	10	2190	59.35	475	31.25
18	Hogana	315	19.44	1120	30.35	630	41.47
19	Madawalabu	102.5	6.33	1230	33.33	475	31.25
20	Hidasie	307.5	18.98	2460	66.67	570	37.5
21	Kingbird	307.5	18.98	2060	55.83	1045	68.75
22	Wane	162	10	1710	46.34	475	31.25
23	DAKA	335	20.68	1230	33.33	570	37.5
24	Balcha	112	6.9	280	7.5	140	9.2
25	Morocco Sus. Ch	1620	100	3690	100	1520	100

AUDPC, area under disease progress curve, rAUDPC relative area under disease progress curve.

3.2. Area Under Disease Curve and Relative Area Disease Progress Curve

Selecting of cultivars with having terminal rust severity less than 30% and coefficient of infection between 0 to 20 are acceptable partial slow rusting in field experiments for practical purpose. The cultivars having rAUDPC values up to 40% of check Morocco were grouped as high level of partial

resistance consisted of six wheat cultivars includes Sanate, Balcha, Dashen, Madawalabu, DAKA and Pavon 76; while those having rAUDPC values up to 70% of check were grouped as moderately resistant to moderately susceptible cultivars, includes Galama, Hogana, Alidoro, Wane, shorima, Kingbird, Danada, Huluka, Hidasie and Lemmu. Of the wheat cultivars having the rAUDPC values between 70 to 100% of check cultivar were grouped as low level of partial resistance includes, Kakaba, PBW 343, Enkoy, Ogolcho, Digalu, Kubsa, Isreal, Lakech and Morocco showed S disease reaction and known as susceptible cultivars over all location. Generally, thrity six percent of the tested materials were grouped as low adult plant resistance and susceptible cultivars that needs effective fungicides with determined spraying frequencies.

According to [29-34] the cultivars with having low terminal rust severities along with coefficient of infection and field selection of slow rusting traits with low rAUDPC preferably feasible where greenhouse facilities are in adequate and experimental stations are hotspot throughout the season. These wheat cultivars initially displayed rust infection and sporulation but the last host reaction was described as chlorotic and necrotic lesions. Consequently, the disease progression continued slower and highly delayed among these cultivars. Such partly resistant cultivars could highly delay evolution of new virulent races of the pathogen because multiple point mutations are very rare in normal [35-37]. Similarly, regardless of the MS infection type displayed on moderately slow rusting cultivars yellow rust established incorrectly as shown by their AUDPC values. None of the tested cultivars were manifested as having resistant field response while 85% of the tested cultivars were clustered as susceptible having S type of field response during the 2020 cropping season. The high and moderate adult plant resistant wheat cultivars recognized in the present study were suggested to be having genes for different degrees of slow rusting and may be used for extra genetic manipulation in wheat development program.

Table 5. *Stripe rust AUDPC and rAUDPC values of commercial cultivars at Kulumsa, Meraro and Bekoji in 2020 cropping season.*

S/NO	Cultivars	Kulumsa		Meraro		Bekoji	
		AUDPC	rAUDPC	AUDPC	rAUDPC	AUDPC	Raudpc
1	Digalu	1400	64.52	2380	100	1540	81.48
2	Kubsa	1750	80.65	2310	97.06	1750	92.59
3	PBW343	1470	67.74	2170	91.18	1540	81.48
4	Dashen	1260	58.06	1295	54.41	385	20.37
5	Lakech	1610	74.19	1890	79.41	1540	81.48
6	Sanate	875	40.32	1400	58.82	1225	64.81
7	Isreal	1400	64.52	1680	70.59	1820	96.3
8	Enkoy	665	30.64	1400	58.82	1190	62.96
9	Pavon 76	805	37.1	1295	54.41	945	50
10	Shorima	1120	51.61	1225	51.47	875	46.3
11	Galama	910	41.94	1890	79.41	1260	66.67
12	Kakaba	1120	51.61	2205	92.65	1190	62.97
13	Ogolcho	1750	80.65	1960	82.35	1820	96.3
14	Danda'a	560	25.81	1120	47.06	805	42.59
15	Lemmu	840	38.71	2030	85.29	525	27.78
16	Alidoro	525	24.19	1225	51.47	700	37.04
17	Huluka	1190	54.83	1365	57.35	1750	92.59
18	Hogana	840	38.71	1085	45.59	1470	77.78
19	Madawalabu	1505	69.36	1365	57.35	1400	74.07
20	Hidasie	1155	53.23	1505	63.24	1120	59.26
21	Kingbird	770	35.48	1960	82.35	1225	64.81
22	Wane	525	24.19	1190	50	560	29.63
23	DAKA	175	8.06	735	30.88	630	33.33
24	Balcha	168	7.74	490	20.59	385	20.37
25	Morocco Sus. ch	2170	100	2380	100	1890	100

AUDPC, area under disease progress curve, rAUDPC relative area under disease progress curve.

4. Conclusion

Most of the evaluated cultivars exhibited low slow rusting performance under high disease pressure shown by susceptible check morocco. Wheat cultivar only Balcha showed lesser levels of FRS (< 30% with MR and MS responses) and coefficient of infection (< 20) signifying a high level of slow rusting resistance over all location. Currently in Ethiopia especially Arsi and West Arsi wheat producing areas are hotspots to the yellow rust epidemics and hence there is a change in races and possibility of happening new races due to lack of varietal deployment law and a change in environment throughout the year. Therefore development of slow rusting resistant varieties and identifying genes with horizontal resistance across with different regions is important to combat the epidemics and reduce yield loss caused by yellow rust. In Ethiopia, 88% of the cultivated cultivars were highly susceptible to wheat yellow rust that cannot be produced without frequent application of fungicides. So wheat producers including formers, Government run and private wheat fields should be supported by effective fungicides to manage its pressure and reduce yield loss caused by yellow rust.

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