Evaluation of Barley for Field Resistance to Scald

Yitbarek Semeane, A. Bainbridge, Bekele Hunde
Institute of Agricultural Research,
P.O. Box 2003, Addis Ababa, Ethiopia

Abstract

Sixteen barley genotypes were evaluated for their resistance to scald (caused by *Rhyncosporium secalis*) in a randomized complete block design with three replications for three seasons at Holetta and for one season at Adet and at Bekoji research centers. Results at Holetta showed that percent infection taken from lower, middle, and upper parts of the plant correlated negatively with yield and 1000 seed weight significantly ($P=0.05$). Correlation coefficients (r) were highest for disease evaluation taken from the middle leaf during most part of the season while high r values were obtained for disease evaluation taken from the lower and upper leaves at early and late stages of the crop development. However, disease assessment made on the middle leaf was adequate for evaluating barley genotypes for field resistance, measured in AUDPC (area under the disease progress curve). Barley genotypes showed marked differences in scald development. The varieties 'Proctor' and 'ARDU-12-8C' had the highest AUDPC values and were extremely susceptible. The varieties 'IAR/H/485', 'HB 52' and 'HB 68' sustained half to one-third the amount of scald recorded on the above susceptible varieties and were rated moderately susceptible. The remaining eleven genotypes showed small AUDPC values with non-significant differences among them and were consistent in all testing seasons. These genotypes seemed to possess field resistance to scald and some of them, such as 'HB 42', 'HB 99' and 'HB 100', also gave high yields at Holetta. Development of scald was lower on plants flanked by three rows of oats than those not flanked. This suggests that the disease progresses independently within plots and could be accelerated due to inter-plot interference.

Introduction

Scald, caused by *Rhyncosporium secalis*, is the principal disease of barley in Ethiopia (Eshetu 1985, Yitbarek 1990). In most barley growing regions of the country, cool temperature and excessive rainfall favor the development of this disease. As barley is cultivated in both the main and "belg" (short rains) season (CSA 1987), this creates no crop-free period and favors abundant inoculum production by the pathogen, which usually leads to heavy disease epidemics. Hence, yield losses of up to 67% have been reported when susceptible genotypes were grown in such environments (Eshetu 1985).

Several high yielding barley varieties have been released in the past (Fekadu, 1987). The usefulness of these varieties depended on their resistance level to the disease. A number of resistant lines, however, have been identified recently from continuous evaluations of available barley germplasm (Yitbarek & Brehanu 1992). The genetic makeup of these lines is not well understood, although they are believed to possess complete resistance. In many instances the usefulness of this type of resistance is short-lived and the control mechanism breaks down because of fast development of virulent races or pathotypes. On the other hand, general or field resistance (a type of resistance characterized by reduced rate of disease development despite a susceptible infection type) is thought to be long lasting. Such types of resistance were found effective in many host-pathogen systems (Padgett et al. 1990, Shanner & Finney 1977, Wilcoxson et al. 1975).

This study was undertaken to understand the development of scald in the field; to evaluate and select field techniques for effective identification of genotypes with field resistance and to identify genotypes that possess rate-reducing resistance which could be used as source of resistance for the breeding program and/or to utilize those with reasonably high yielding genotypes for commercial use.

Materials and Methods

Sixteen barley genotypes were used for this test. Each entry was planted in plot of 10 rows of 0.2 m distance between rows and 2.5 m length in a randomized complete block design, replicated three times. The experiment was conducted for three seasons between 1988 and 1990 at Holetta, and also at Bekoji and Adet research centers during the third season. Except early planting (June 14 to 16) at Holetta, all agronomic practices were as recommended for respective centers. Plots were inoculated at 2 to 3 leaf stage by distributing 60 g infected stubble in each plot, to supplement the natural infection. Each plot was flanked with 3 rows of oat to reduce inter-plot interference in all locations. A similar experiment, but without flanking with oat, was carried out for one season at Holetta to observe the effect of isolation with oat on scald development.

Percent leaf infection was assessed on 20-25 plants per plot. Two to three leaves at the lower, middle, and upper plant parts were assessed at 7-10 day intervals. Seven to eight such assessments were made each season at Holetta, but only three assessments were made at Bekoji. At Adet, percent infection was assessed on all plants in each plot, seven times in a season. Simple linear correlations were made between disease assessments at the different crop canopy and assessment dates and yield parameters. Area under disease progress curve (AUDPC) was calculated using the formula described by Shanner and Finney (1977).

$$\sum_{i=1}^{n} (1/2(I_1+I_2))(T_2-T_1)$$

Where I_1 and I_2 were percent infection; T_1 and T_2 were time for disease assessments at dates 1 and 2, respectively, and n is total number of observations. The AUDPC values of the middle canopy were used to calculate the analysis of variance.

Results and Discussion

Supplementing the natural infection with infected stubble caused heavy epidemics at Holetta in all seasons. Simple correlations between disease assessments made at different weeks to seed weight and yield showed significant negative relations (Table 1). Although disease observed early in the season influenced yield significantly, generally r values for mid and later assessments were relatively high. Disease assessments made at the lower, middle, and upper plant parts had all significant relationships with yield as well as seed weight. Overall disease assessments made at the middle part of the plant during the season had higher values of r than the lower or upper plant parts.

James et al. (1968) demonstrated the importance of the first and second leaves in contributing most to grain filling of the crop using critical point model for disease observed at a particular growth stage. A non-significant difference among critical point, multiple linear regression model, and area under disease progress curve was also reported in a similar study and showed a significant correlation of the upper three leaves to yield (Khan and D'Antuono, 1985). However, information is lacking on the importance of scald at the lower part of the plant to yield. The present study showed a significant correlation of scald on lower leaves to yield, and demonstrated that a disease that appeared early in the season has a significant effect on yield. This may suggest flexibility on time of scald assessment during crop development at least for the Holetta area.

Combined analysis of variance of AUDPC and yield showed a non- significant variation between seasons at Holetta. Therefore, three years data were pooled for the analysis in comparing the genotypes. Genotypes showed similar pattern of variation for disease assessment at the lower, middle, and upper parts of the plant in all the seasons. However, AUDPC at the middle part of the plant was used since AUDPC at the lower part overestimated the disease on resistant genotypes and AUDPC at upper part underestimated disease on susceptible genotypes. Based on the AUDPC values the genotypes could be classified into five groups (Table 2).

Table 1. Correlation coefficients between percent infection by *R. secalis* at different plant parts and observation weeks for 1000 seed weight and yield of barley genotypes grown at Holetta, 1988-1990

Sampling month (week)	Number of observations	Plant part	Seed weight		Yield	
			r value	T value	r value	T value
August (1)	144	Lower	-0.38	4.904	-0.58	8.554
	144	Middle	-0.34	4.332	-0.49	6.627
	144	Upper	-0.29	3.606	-0.37	4.740
August (2)	144	Lower	-0.39	4.992	-0.60	8.833
	144	Middle	-0.42	5.527	-0.60	8.965
	144	Upper	-0.40	5.127	-0.54	7.614
August (3)	96	Lower	-0.56	6.499	-0.62	7.619
	96	Middle	-0.56	6.585	-0.60	7.355
	96	Lower	-0.56	6.036	-0.57	6.650
August (4)	135	Lower	-0.37	4.631	-0.65	9.736
	144	Middle	-0.49	6.702	-0.70	11.628
	144	Upper	-0.49	6.757	-0.61	9.160
September (1)	133	Lower	-0.37	4.562	-0.65	9.654
	144	Middle	-0.50	6.898	-0.73	12.753
	144	Upper	-0.50	6.897	-0.66	10.411
September (2)	96	Lower	-0.42	4.545	-0.62	7.658
	96	Middle	-0.51	5.733	-0.71	9.690
	96	Upper	-0.52	5.846	-0.71	9.767
September (3)	83	Lower	-0.38	3.733	-0.51	5.315
	96	Middle	-0.52	5.897	-0.66	8.435
	96	Upper	-0.55	6.345	-0.69	9.132
September (4)	96	Lower	-0.38	3.965	-0.59	7.003
	96	Middle	-0.49	5.281	-0.66	8.568
	96	Upper	-0.54	6.253	-0.70	9.669
October (1)	79	Lower	-0.22	1.956	-0.56	5.931
	96	Middle	-0.42	4.474	-0.70	9.417
	96	Upper	-0.46	5.001	-0.72	9.990

All values are significant at p=0.01, except (+) which is significant at p=0.05.

The first group included the genotypes 'Proctor' and 'ARDU-12-8C' with the AUDPC values as high as 4186 and were considered truly susceptible. The disease on these genotypes started early and increased rapidly as the season progressed and finally levelled off towards the end of the season (data not shown). In the second group the genotype 'IAR/H/485' showed a similar scald development but with a lower AUDPC value. The third group included 'HB 52' and 'HB 68, with intermediate AUDPC values of 1956 to 2241 and were relatively less susceptible than the previous two groups. Disease development on these genotypes started early but disease epidemics showed steady growth with final disease lower than the other groups. The fourth group included 'HB 100', 'Holker', 'Balker' and 'ARDU-12-9C' with the AUDPC values less than 700 and a slow disease development that resulted in low levels even at the end of the season. The fifth group consisted of the remaining seven genotypes which were characterized by low AUDPC values of 16.6-131.8 because of reduced rate of disease development. Genotypes were also compared using the apparent infection rate calculated from the first year data (data not presented). However, mean separations were not as distinct as the AUDPC values.

Table 2. Comparison of scald development as measured by the AUDPC value at the middle plant part of flanked and unflanked plots of genotypes.

Genotype	AUDPC*	
	Flanked	Unflanked
ARDU-12-8C	3862.0 a	3795.0 a
Proctor	3255.0 b	3862.0 a
IAR/H 485	1856.0 c	1330.0 cd
HB 68	1864.0 c	2057.0 b
HB 52	1076.0 d	1685.0 bc
Balker	240.3 e	392.0 gh
Holker	217.0 e	501.7 efg
HB 100	157.5 e	875.0 ef
HB 15	12.8 e	100.3 gh
ARDU-12-9C	7.0 e	936.8 de
Ahor 880/61	2.3 e	448.0 fgh
Beka/S	0.0 e	81.7 gh
ARDU-12-60B	0.0 e	184.3 gh
HB 7	0.0 e	45.5 gh
HB 42	0.0 e	2.3 h
HB 99	0.0 e	0.0 h

Means within a column followed by the same letter are not significantly different (p=0.05) according to Duncan's Multiple Range Test.

The reliability and convenience of AUDPC over the apparent infection rate in measuring the rate reducing resistance have been demonstrated in several occasions (Padgett et al. 1990, Shanner & Finney 1977, Wilcoxson et al. 1975). Slow scalding has been reported in barley by van Ginkel and Vivar (1986). However, their result was not comparable to ours due to differences in field experimentation, environmental conditions, and the pathogen population and genotypes used. In our study most of the genotypes that had lower AUDPC value probably possess rate reducing resistance, or field resistance. Rate reducing resistance in barley to scald has not been adequately reported in the literature. This study may, however, indicate the presence of this phenomenon in the Ethiopian genotypes.

The genotypes 'HB 42', 'HB 68', 'ARDU-1260B' and 'Balker' produced heavier seeds while 'HB 99', 'HB 42' and 'HB 100' gave higher yield than the other genotypes. These are all in the fifth group that are believed to possess field resistance to scald. The commercial variety 'ARDU-12-60B' possessed a reduced scald development although its yield was lower than the above mentioned genotypes.

Analysis of variance for disease and yield showed considerable variation among locations and it was not possible to pool data to compare genotypes across locations. The comparison was, therefore, made for each location (Table 3). The genotypes 'HB 15' and 'Beka/S' were the only entries with the lowest AUDPC values in all locations. The genotypes 'Balker', 'Ahor 880/61', 'ARDU-12-60B', 'ARDU-12-9C' and 'HB 42' had low AUDPC values at two of the three locations. By contrast, 'Proctor' and 'ARDU-12-8C' had the highest AUDPC values in all locations. 'Holker' yielded high in all locations while 'ARDU-12-60B', 'HB 42' and 'HB 100' yielded high at two of the three locations.

Field resistance of barley to *R. secalis* was demonstrated in different environments with little fluctuations that could be attributable to differences in pathogen population. However, this evidence required more extensive studies by exposing genotypes to diverse environments where population of the pathogen is expected to be different. There is also a need to investigate the mechanism of this resistance and possibly by exposing genotypes to single and mixtures of races of the pathogen. Although little is known about the inheritance and durability, this type of resistance will be useful to identify resistant parents that could be used for breeding to scald resistance.

Table 3. Development of scald as AUDPC at middle part of plants, 1000 seed weight, and yield of genotypes evaluated for field resistance to scald during 1988-1990 at Holetta.

Genotype	AUDPC	Seed weight (g)	Yield (q ha^{-1})
Proctor	*4186.0 a**	*21.9 j*	*16.5 h*
ARDU-12-8C	*4022.0 a*	*29.9 h*	*9.0 i*
IAR/H/485	*2607.0 b*	*33.2 g*	*26.1 fg*
HB 52	*2241.0 c*	*35.6 ef*	*25.9 fg*
HB 68	*1956.0 c*	*42.5 b*	*23.0 g*
HB 100	*606.7 d*	*27.0 i*	*34.1 bc*
Holker	*552.9 d*	*37.4 d*	*31.7 cde*
Balker	*459.9 d*	*40.0 c*	*32.2 cd*
ARDU-12-9C	*452.1 d*	*37.7 d*	*32.9 cd*
Beka/s	*131.8 e*	*34.0 fg*	*27.4 ef*
Ahor 880/61	*40.0 e*	*37.3 de*	*32.2 cd*
HB 99	*37.2 e*	*34.9 fg*	*39.5 a*
HB 15	*36.8 e*	*34.2 fg*	*30.2 cdef*
HB 7	*30.2 e*	*35.3 f*	*29.5 cde*
ARDU-12-60B	*28.3 e*	*41.0 bc*	*29.9 cdef*
HB 42	*16.6 e*	*51.3 a*	*37.5 ab*

**Means within a column followed by the same letter are not different (p=0.05) according to Duncan's Multiple Range Test.*

Disease development considerably varied between unflanked and flanked plots by three rows of oats. Most genotypes had more disease when plots were not flanked (Table 4). This indicates that movement of inoculum between plots was reduced by isolating them with oats. The level of disease was between 1.2 to 194 times more in unflanked plots than in flanked plots. The highest difference was observed on 'Ahor 880/61' and the lowest on 'Proctor'. Parlevliet and Ommeren (1984) demonstrated the importance of isolation and the role of inter-plot interference in evaluating genotypes for partial resistance to leaf rust. They suggested that the partial resistance of a genotype was underestimated due to an adjacent susceptible variety. In this study, the non-significant differences obtained between flanked and unflanked plots for the genotypes 'Proctor', 'IAR/H/485' and 'ARDU-12-8C' is not surprising since these were susceptible genotypes and probably served as exporter of inoculum that caused more disease on unflanked adjacent plots.

Table 4. Development of scald as measured by AUDPC at middle leaves and yield of genotypes tested at Holetta, Bekoji and Adet, 1990.

Genotype	AUDPC			Yield q/ha		
	Holetta	Bekoji	Adet	Holetta	Bekoji	Adet
ARDU-12-8C	3862 a	2785 a	1463 a	7.4 f	32.1 f	13.3 fg
Proctor	3255 b*	2813 a	1525 a	18.2 e	34.3 ef	14.9 ef
HB 68	1864 c	558 cd	952	20.4 e	38.9 edef	13.3 fg
IAR/H 485	1856 c	16 f	942 b	23.8 cde	43.1 abcd	21.5 cd
HB 52	1076 d	1555 b	724 c	23.5 de	37.9 cdef	22.2 bcd
Balker	240 e	25 f	265 def	30.2 a-d	37.9 cdef	22.7 bcd
Holker	217 e	141 ef	282 def	29.9 abcd	44.7 abcd	27.6 ab
HB 100	157 e	319 e	461 d	33.4 ab	45.8 abc	22.4 bcd
HB 15	12 e	0 f	224 efg	24.3 cde	36.6 def	23.9 bcd
ARDU-12-9C	7 e	0 f	435 de	31.8 abc	41.6 bcde	23.9 bcd
Ahor 880/61	2 e	62 ef	52 g	31.8 abc	38.0 cdef	20.7 cd
Beka/S	0 e	0 f	224 efg	18.4 3	34.4 ef	9.3 g
ARDU-12-60B	0 e	0 f	343 def	19.6 e	49.9 a	23.3 bcd
HB 7	0 e	635 c	349 def	25.8 bcde	39.9 bcdef	25.8 abc
HB 42	0 e	312 de	211 fg	29.9 abcd	47.9 ab	29.3 bcd
HB 99	0 e	231 ef	413 def	36.6 b	38.7 cdef	22.3 bcd
						18.9 de

Means in a column followed by the same letter are not different (p=0.05) according to Duncan's Multiple Range Test

References

CSA (Central Statistics Authority). 1987. Time series data on area, production and yield of major crops 1979/80-1985/86. Statistical Bulletin No. 56. CSA: Addis Ababa, Ethiopia. 242 pp.

Eshetu Bekele. 1985. A review of research on diseases of barley, tef and wheat in Ethiopia. pp. 77-108. In A Review of Crop Protection Research in Ethiopia, Abate T (ed.). Institute of Agricultural Research (IAR): Addis Ababa, Ethiopia.

Fekadu Alemayehu. 1987. Barley Improvement Program. Recommendations and Strategies. pp. 77-89 Proceeding of the 19th National Crop Improvement Conference, 22-26 April, 1987. IAR: Addis Ababa, Ethiopia.

James WC, Jenkins JEE, Jemmetti JC. 1986. The relationship between leaf blotch caused by *Rhynchosporium secalis* and losses in grain yield of spring barley. Annals of Applied Biology **62**:273-288.

Khan TN, D'Antuono MF. 1985. Relationship between scald (*Rhynchosporium secalis*) and losses in grain yield of barley in Western Australia. Australian Journal of Agricultural Research **36**: 655-661.

Padgett GB, Nutter FW Jr., Kuhn CW, All JN. 1990. Quantification of disease resistance that reduces the rate of tobacco etch virus epidemics in bell pepper. Phytopathology **80**:451-455.

Parlevliet JE, Ommeren A van. 1984. Interplot interference and assessment of barley cultivars for partial resistance to leaf rust, Puccinia hordei. Euphytica **37**:685- 697.

Shanner G, Finney RE. 1977. The effect of nitrogen fertilization on the expression of slow-mildewing resistance in knox wheat. Phytopathology **67**:1051-1056.

Van Ginkel M, Vivar HE. 1986. Slow scalding in barley. Rachis **5**:15-17.

Wilcoxson RD, Skovmand B, Atif AH. 1975. Evaluation of wheat cultivars for ability to retard development of stem rust. Annals of Applied Biology **80**:275-281.

Yitbarek Semeane. 1990. Curent status of barley diseases in Ethiopia. pp. 37-41. In Proceedings of the Ethiopian Phytopathological Committee (EPC) Annual Meeting, Seid Ahmed, Yaynu Hiskias (eds.). EPC: Addis Ababa, Ethiopia.

Yitbarek Semeane, Brehanu Lakew. 1992. Field evaluation of barley (*Hordeum vulgare* L.) for resistance to scald. Rachis **11**: