Yield Loss Due to Leaf Rust on Barley at Different Sowing Dates

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Abstract

Yield loss studies on barley due to barley leaf rust (BLR), caused by *Puccinia hordei* Otth., were conducted for three years between 1994 and 1996 at Ambo Plant Protection Research Centre of the Institute of Agricultural Research. A susceptible variety 'Trompillo' was used. The experiments were conducted in a split plot design with four sowing dates assigned to main plots and fungicide unsprayed and sprayed treatments to subplots. Means of disease severity for unsprayed treatments ranged from AUDPC 661-1278 while that of the sprayed treatments were 0.0. Late planting had a negative effect on grain yield (GY) and thousand kernel weight (TKW). Moreover, the fungicide unsprayed treatments were significantly lower in GY, TKW and kernels per spike (KPS) as compared to the sprayed treatments. Interaction effects between sowing date and fungicide treatments were also significant. Differences between unsprayed and sprayed treatments increased in all selected yield parameters as the sowing date was delayed. The losses in GY due to BLR for the four sowing dates ranged from 6.9 to 40.2 percent; for TKW from 5.9 to 27.6 percent and for KPS from 0 to 16.5 percent. Under normal sowing date (June 16), the losses for GY, TKW and KPS were 23.4, 14.3 and 0.2 percent, respectively. There were highly significant negative correlations between BLR severity and GY, and between BLR and TKW. These results confirm the economic importance of BLR on barley at Ambo.

Introduction

Barley leaf rust, caused by *Puccinia hordei* Otth., is a common fungal disease in the highlands of Ethiopia (Dagnachew 1967). The disease was first reported in Ethiopia by Stewart and Dagnachew (1967) and has become widespread in all barley growing regions of Ethiopia causing heavy losses (Fekadu 1995). Surveys conducted in the past indicated a severity range of 80 to 100 percent in many fields of Arsi, Bale, Wellega, Gojam and parts of Shewa regions (SPL 1986). Epidemics of leaf rust have been recorded in the Ambo, the Adet, the Sinana, the Shashemene and the Jima areas (Yitbarek et al. 1996, Getaneh & Temesgen 1996).

The disease is characterized by small, round, yellow-brown pustules occurring mainly on the leaves or leaf sheaths. Later in the season round to oblong, dark brown, telial pustules develop (Stubbs et al. 1986). The uredia often serve as sources of primary inoculum of this pathogen. Long distance dispersal of the urediospores is by way of wind (Stubbs et al. 1986).

Barley leaf rust is known to cause serious yield losses in the countries of North Africa and in Pakistan (Stubbs et al 1986). A yield loss of 23% was registered in Canada (Melville et al. 1976). In Holland, heavily and lightly rusted barley were sprayed with a fungicide at heading time and yield increases of 30 and 10 percent, respectively, were obtained (Melville et al. 1976). Similar work in England also showed yield increases of 17 to 31 percent (Melville et al. 1976). Moreover, losses can be great particularly when the pathogen infects plants early and also infects the flag leaf (King & Polley 1976). It causes shrivelled kernels, a decrease in kernel number, adverse effect on malting quality (Stubbs et al. 1986, Mathre 1987) and reduces vigour and plant growth by increasing transpiration, respiration and reducing photosynthesis (Sapkal et al. 1992). Losses due to barley leaf rust vary with sowing date (Peresipkin 1979, Melville et al. 1976). Yield losses are often more in late drilled crops than early ones (Peresipkin 1979, Melville et al. 1976). However, there is a lack of information on the development of foliar diseases and their effects on the yields of barley planted at different sowing dates in Ethiopia. Attempts made to study yield losses due to the disease failed because of interference of other diseases (Eshetu 1985). The purposes of this study were to determine the economic importance of barley leaf rust and its effect on yields of barley planted at different sowing dates.

Materials and Methods

The barley variety 'Trompillo', which is susceptible to barley leaf rust, but resistant to other major leaf diseases, was hand sown at the Ambo Plant Protection Research Centre of the Institute of Agricultural Research during the 1994, 1995 and 1996 cropping seasons. The effects of sowing dates and fungicide application were compared using a split plot design with four replications. Four sowing dates (June 1, June 16, July 1 and July 16) were assigned to main plots, and fungicide treatments (sprayed and unsprayed) to sub-plots. Plots were 6 rows of 2.5 m length and 1.2 m width. The net plot was four central rows of 2.0 m by 0.8 m. To reduce spray drifts, buffer zones were created by planting three rows of oats between plots and replications. The fungicide propiconazole (Tilt) was applied on the chemically treated plots every 10 days at the rate of 0.5 l ha^{-1}. The trials were carried out under natural barley leaf rust infection.

Barley leaf rust severity was estimated by taking the percent leaf area affected at 10 days interval, starting from the first appearance of the symptom. Such ratings were taken five times during the growing period. The area under disease progress curve (AUDPC) was computed from the percentage leaf area affected. The growth stage of the plants was recorded by using Zadoks' scale as modified by Stubbs et al. (1986). Yield loss was calculated as the difference between mean yield of fungicide sprayed and unsprayed plots (FAO 1971). Thousand kernel weight and kernel number per spike losses were computed similarly. Barley leaf rust severity, grain yield per hectare, thousand kernel weight and kernel number per spike of unsprayed and sprayed plots within the same and across sowing date(s) were compared by using analysis of variance and least significant difference tests. Correlation analyses were calculated for barley leaf rust severity and selected yield parameters.

Results

The overall mean severity of barley leaf rust, as expressed by AUDPC, for the 3 years, during 1994 to 1996 cropping seasons, ranged from 661 to 1277.7. The severity of the disease increased significantly between the first (June 1) and the last three (June 16, July 1 and July 16) sowing dates. There were no significant differences in the disease severity among the last three sowing dates. However, infection started earlier on the second (June 16) than on the first, on the third than on the second, and on the fourth than on the third sowing dates, which enabled the disease to have more time to cause more damage to the crop (Table 1).

Yield of barley crop was negatively affected by late sowing date. Grain yield decreased significantly as the sowing date was delayed. The highest mean yields were obtained from earlier sowing dates. The mean grain yields of the fungicide unsprayed treatments were significantly lower due to the disease as compared to the sprayed treatments. The differences between the two treatments increased as the date of planting was delayed. There were also highly significant differences in the sowing date by fungicide treatment interactions. Hence, grain yield losses due to barley leaf rust ranged from 6.9% for the first to 40.2% for the last sowing dates. The loss under normal sowing date (June 16) was 23.4% (Table 1). Reference to Table 2 indicates that the differences in thousand kernel weight were

Table 1. Effects of *Puccinia hordei* on grain yield of the susceptible barley variety 'Trompillo' planted at four sowing dates at Ambo, 1994-1996 crop seasons.

Sowing date	Growth* stage	AUDPC**		Yield (Kg ha-1)			Loss
		S	US	S	US	SD	(%)
June 1***	5	0.0	661.0	4444.0	4138.0	4291.1	6.9
June 16	4	0.0	1277.7	4458.0	3414.1	3936.0	23.4
July 1	3	0.0	1173.7	4350.9	3104.9	3727.9	28.6
July 16	2	0.0	1040.7	3449.0	2063.1	2756.2	40.2
Mean		0.0	1038.3	4175.5	3180.1	-	-
CV (%)	7.4						
LSD (0.01)							
Sowing date (SD)	932.5						
Fungicide (FG)	NS						
SD x FG	586.5						

** Growth Stage: 5=heading, 4=booting, 3=stem elongation and 2=tillering.*
*** S = Sprayed and US = Unsprayed.*
****Means for 1994 and 1996 crop seasons only*

highly significant among the sowing dates, between the fungicide unsprayed and sprayed treatments, and with their interactions. The difference in thousand kernel weight was probably because the weather condition had a negative effect on the plumpness of barley kernels when planted late. The highest thousand kernel weight was recorded for the first and the least for the fourth sowing date. But, the difference between the unsprayed and sprayed treatments was the effect of barley leaf rust on the crop, and it increased as the sowing date was delayed. The losses ranged from 5.9% for the first to 27.6% for the fourth sowing date. The loss for the normal sowing date was 14.3%.

The effect of barley leaf rust on kernel number per spike is shown in Table 3. Means of kernel number per spike were statistically the same among the sowing dates, indicating that kernel number was not affected by planting date. Barley leaf rust severity has increased gradually, but the variation was significant between the first two and the last two sowing dates. This difference has been reflected in the increased losses in the number of kernels per spike between unsprayed and sprayed treatments in the last two sowing dates. The interaction of the sowing date by fungicide treatment was also significant. Losses ranged from zero percent for the first to 16.5% for the last sowing dates. The loss for the normal sowing date was 0.25.

Barley leaf rust severity had negative significant effects on grain yield ($r=-0.574$, $P<0.01$) and on thousand kernel weight ($r=-0.743$, $P<0.01$). There was also a negative correlation between the disease and kernels per spike, but these relations were not significant ($r=-0.256$, $P=0.05$).

Table 2. Effects of *Puccinia hordei* on thousand kernel weight (TKW) of the susceptible barley variety 'Trompillo' planted at four sowing dates at Ambo, 1994-1996 crop seasons.

Sowing date	AUDPC		TKW (g)			Loss
	S	US	S	US	SD	(%)
June 1*	0.0	661.0	33.8	31.8	32.8	5.9
June 16	0.0	1277.7	31.4	26.9	29.2	14.3
July 1	0.0	1173.7	29.9	22.7	26.3	24.1
July 16	0.0	1040.7	28.6	20.7	24.7	27.6
Mean	0.0	1038.3	30.9	25.3	-	-
CV (%)	4.1					
LSD (0.01)						
Sowing date (SD)	2.7					
Fungicide (FG)	NS					
SD x FG	2.5					

Table 3. Effects of *Puccinia hordei* on the number of kernels per spike of the susceptible barley variety 'Trompillo' planted at four sowing dates at Ambo, 1994-1996 crop seasons.

Sowing Date	Growth Stage	AUDPC		Kernel per spike			Loss (%)
		S	US	S	UN	SD mean	
June 1	5	0.00	707.0	42.7	42.7	42.7	0.00
June 16	4	0.0	918.0	39.7	39.6	39.6	0.2
July 1	3	0.0	1016.0	43.0	40.7	41.8	5.3
July 16	2	0.0	1107.0	51.5	43.0	47.2	16.5
Mean	-	0.0	937.0	44.2	41.5	-	-
CV (%)	5.8						
LSD (0.05)							
Sowing date (SD)	NS						
Fungicide (FG)	NS						
SD x FG	3.8						

Discussion

Barley leaf rust appeared on the first sowing date at growth stage 5, while on the second sowing it was at growth stage 4, or about 9 days earlier than on the first. On the third sowing date, the rust appeared at growth stage 3, or 16 days earlier than on the first and on the fourth, it was seen at growth stage 3, or 21 days earlier than on the first sowing date. The mean barley leaf rust severity increased significantly between the first and the rest of the sowing dates. The losses in grain yield and thousand kernel weight were also different accordingly. In the later three sowing dates, however, the disease severity was similar.

In contrast, the grain yield, thousand kernel weight and kernel number per spike losses increased as the sowing date was delayed. As indicated above, the infection period for each sowing date increased as the sowing date progressed further.

The exposure of barley crop for the disease was the longest on the fourth and the least on the second sowing date. This would mean that the earlier the infection, the more losses the disease caused. Consequently, even though the later three sowing dates had similar disease severity, the losses in grain yields increased from 23.4 to 40.2 percent, for thousand kernel weight from 14.3 to 27.6 percent, and for kernel number from 0.2 to 16.5 percent. This result is in agreement with that of Mathre (1985) which indicated that losses could be great particularly when the pathogen infects the crop at early growth stage or the time of arrival of the inoculum in relation to the stage of the crop development is one of the major factors that determines the amount of losses (Rasmusson et al. 1985). In addition, the losses could also be increased because the unsprayed treatments reached maturity much earlier (10 days) than on the sprayed ones, and there could also be a loss of characteristically small grains in unsprayed plots during threshing.

The similarity of barley leaf rust severity among the later three sowing dates may be partly due to limitations in the accuracy of disease assessment. In particular, assessment was confined to the leaf lamina whereas field observations indicated that in the unsprayed plots infection of the leaf sheath was common especially during 1995 crop season and could have continued to affect yield after death of the leaf lamina.

In the first sowing date, when barley was affected at heading stage, the loss was due to the reduction in kernel size. But, when the crop was infected earlier than heading stage, loss in kernel number per spike was observed. This loss increased and reached the maximum on the fourth planting date (Table 3). These findings agree with those of Melville (1976) which said that barley leaf rust infection after heading decreased grain weight and infection before heading was likely to affect either tiller number or number of grains per spike.

Grain yields and thousand kernel weights of the four sowing dates were significantly different. The maximum yield and kernel weight obtained were on the first sowing date and declined as the sowing dates progressed late in the season. This could be the adverse effect of the weather condition that prevailed at the end of the rainy season for the late sown barley. In September and October, the rain was less than in earlier months. Similar results were also recorded at Holetta Research Centre in 1971/72 season (IAR 1972) but the reason for this was not explained.

The highly significant correlation between the thousand kernel weight and the severity of leaf rust suggest that the disease influences the yield of barley mainly through its effect on the kernel weight.

This study has confirmed the economic importance of barley leaf rust, caused by *Puccinia hordei*, on barley and it is suggested that the barley improvement programme should include activities to tackle this disease.