On-farm Yield Loss Due to Leaf Rust (*Puccinia hordei* Otth) on Barley

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Abstract

Barley yield loss assessment study due to barley leaf rust was conducted by superimposing on an already planted white seeded local barley variety on farmers fields at Tikur Inchini and Shenen districts of West Shewa zone for three seasons starting in 1995. The trial was laid out in a randomized complete block design with a paired (fungicide unsprayed and sprayed) treatment and replicated at four sites. Depending up on the growth stages of the crop at which barley leaf rust infection started on the unsprayed treatments, the progress of the disease varied from AUDPC 2841.7 in 1995 to AUDPC 1365.0 in 1996 seasons with a mean AUDPC 1932.8. It was zero on the sprayed treatments. Yield losses also varied according to the development of the disease. Mean leaf rust severity on the unsprayed treatment was significantly higher than on the sprayed treatment, while mean grain yield and thousand kernel weight (TKW) on the unsprayed treatments were significantly lower than on the sprayed treatments. The mean variation between the two treatments, however was by far less in kernel number per spike (KNS^{-1}) and least in number of productive tillers (NPT^{-1}) per plot. Hence, mean losses caused by barley leaf rust were 28.3% for grain yield; 16.6% for TKW, 7.2% for KNS^{-1} and 4.8% for NPT^{-1}. To minimize these losses effective control measures have to be designed.

Introduction

Barley leaf rust caused by *Puccinia hordei* Otth was first reported in Ethiopia by Stewart and Dagnachew (1967). It is a common fungal disease in barley growing regions with altitudes between 2000 and 3000 meters above sea level (masl) (Stewart and Dagnatchew 1967, Berhane et al. 1996). However, it is more prevalent at altitudes below 2450 m where it can cause economic losses. The disease seems less important at altitudes above 2450 m because it occurs late in the season (Fekadu 1995, Getaneh and Temesgen 1996). Barley leaf rust survey conducted in the past indicated a severity ranging from 80 to 100% in many barley fields of Arsi, Bale, Wellega, Gojam and parts of Shewa regions (Getaneh 1998). Moreover, a baseline study conducted in 1994 in the highlands of Tikur Inchini and Ambo districts of West Shewa zone also showed the prevalence of the disease on barley (Chilot and Elias 1998). Epidemics of barley leaf rust have been recorded in Ambo (2225 masl), Adet (2240 masl), Sinana (2400 masl), Shashemene (2050 masl) and Jima (2000 masl) areas (Yitbarek et al. 1996, Getaneh and Temesgen 1996).

Barley leaf rust is widely distributed in the Mediterranean countries and is known to cause particularly serious yield losses in the countries of North Africa and in Pakistan (Stubbs et al. 1986). A yield loss of 23% was reported in Canada (Melville et al. 1976). In Holland, heavily rusted barley field was sprayed with zineb at heading stage and yield increase of 30% was obtained (Melville et al. 1976). In England, the application of fungicide against barley leaf rust had increased barley yield by 17 to 31% (Melville et al. 1976). Yield loss studies conducted on the experimental fields at Ambo Plant Protection Research Centre (PPRC) in four sowing dates revealed losses ranging from 6.9 to 40.2%. Minimum infection and insignificant yield loss were observed in early sown barley, while severe attacks and high yield loss were recorded in late sown barley crop (Getaneh 1998). Losses can be great when barley is affected at earlier growth stages (King and Polley 1976, Melville et al. 1976). Severe early infection causes shrivelled kernels and a slight decrease in grain number (Stubbs et al. 1986). Moreover, barley leaf rust may also reduce vigour and plant growth by increasing transpiration, respiration and reducing photosynthesis (Sapkal et al. 1992).

Quantifying losses caused by barley leaf rust under farmer's conditions is very important to set priorities in the disease management strategies. Information on yield loss assessment is available for on-station studies and there is a need for such information also on farmer's fields to understand the possible associations between the two situations. This paper therefore, presents the efforts made to quantify yield losses caused by barley leaf rust on farmer's fields in Tikur Inchini and Shenen districts (2420 to 2525 masl) of West Shewa Zone.

Materials and Methods

Barley yield loss assessment study due to barley leaf rust was carried out by superimposing on an already planted white seeded local barley variety on farmers fields in West Shewa zone (Tikur Inchini and Shenen districts) for three consecutive seasons (1995-1997). The trial was laid out in a randomized complete block design with four farmer's fields as replications. Each field consisted of one control (unsprayed) and one fungicide sprayed treatments. A plot size of 10 m x 10 m was used. A net plot size of 1.5 m x 1.5 m was taken at five points along the two diagonals of each plot for any measurable traits. The fungicide Triadimenol (Bayfidan) was sprayed on the treated plots every 10 days at the rate of $0.5\ lha^{-1}$. Barley leaf rust and other foliar diseases severity were estimated by examining the whole plants in a plot before each spray was applied using percentage leaf area affected and 0 - 9 scoring scale, respectively (Stubbs et al. 1986). Such ratings were taken four to five times during the growing period. For leaf rust, area under disease progress curve (AUDPC) was computed from the percentage leaf area affected using the formula by Shanner and Finney (1977).

$$\sum_{I=1}^{n} \{½ (I_1 + I_2)\} (T_2 - T_1)$$

Where, I_1 and I_2 were percent infection, T_1 and T_2 were time for disease assessments of dates 1 and 2, respectively and n is total number of observations.

Plant growth stages were recorded by using Zadoks scale as modified by Tottman and Makepeace (Stubbs et al. 1986). Rainfall and mean monthly temperature of the area were recorded (Fig.1). Yield loss was calculated as the difference between mean yield of fungicide sprayed and unsprayed treatments times hundred over the mean yield of the sprayed treatments. Losses in thousand kernel weight, kernel number per spike and number of productive tillers per plot were computed similarly (FAO 1971). Yield and yield components were analysed by using the "t" tests.

Results

Barley leaf rust infection started at growth stage 3 (stem elongation) in 1995 and at growth stages 4 to 5 (booting to heading) in 1997. The latest infection was recorded at growth stages 5 to 6 (heading to flowering) in 1996. Depending on the growth stages of the crop at which barley leaf rust infection started on the fungicide unsprayed treatments, the development of the disease varied from AUDPC 2841.7 in 1995 to AUDPC 1365.0 in 1996 with a mean AUDPC of 1932.8. It was zero on the sprayed treatments (Tables 1- 4). Significant ($P < 0.05$) differences in barley leaf rust infection between the fungicide unsprayed and sprayed treatments were recorded in all the three seasons (Tables 1 - 3). The mean difference of the disease between the two treatments was also significant at $P < 0.05$ (Table 4). Net and spot blotches infection ranged from 1 to 3 score and they were not controlled by fungicide spray.

The effects of barley leaf rust on the grain yields, thousand kernel weights, kernel number per spike and number of productive tillers per plot of the white seeded local barley variety at Tikur-Inchini and Shenen districts of West Shewa zone during 1995 to 1997 cropping seasons are presented in Tables 1- 4. Yield and yield component variations between the unsprayed and sprayed treatments were compared for each year. The degree of variations between the two treatments in grain yield and thousand kernel weight were highly significant ($P < 0.01$) in 1995, but not in 1996 and 1997 crop seasons. As a result, maximum yield loss of 35.1% was recorded when the crop was affected at growth stage 3 and the disease development was the highest (AUDPC = 2841.7). Yield loss reached 28.8% as the crop was infected at growth stages 4 to 5 and the disease progress reduced to AUDPC 1591.7 in 1997. As the crop was infected at growth stages 5 to 6, the progress of barley leaf rust infection (AUDPC = 1365.0) and yield loss (18.7%) were the least in 1996. The losses in a thousand kernel weights, kernel number per spike and number of productive tillers per plot had similar trend as the loss in grain yields. The three years mean differences between the unsprayed and sprayed treatments in barley leaf rust, grain yield and thousand kernel weight were significant ($P < 0.05$). But, the variations between the two treatments in kernel number per spike and number of productive tillers per plot were not significant. The mean losses caused by the disease were 28.3% for the grain yield, 16.6% for thousand kernel weight, 7.2% for kernel number per spike and 4.8% for number of productive tillers per plot (Table 4).

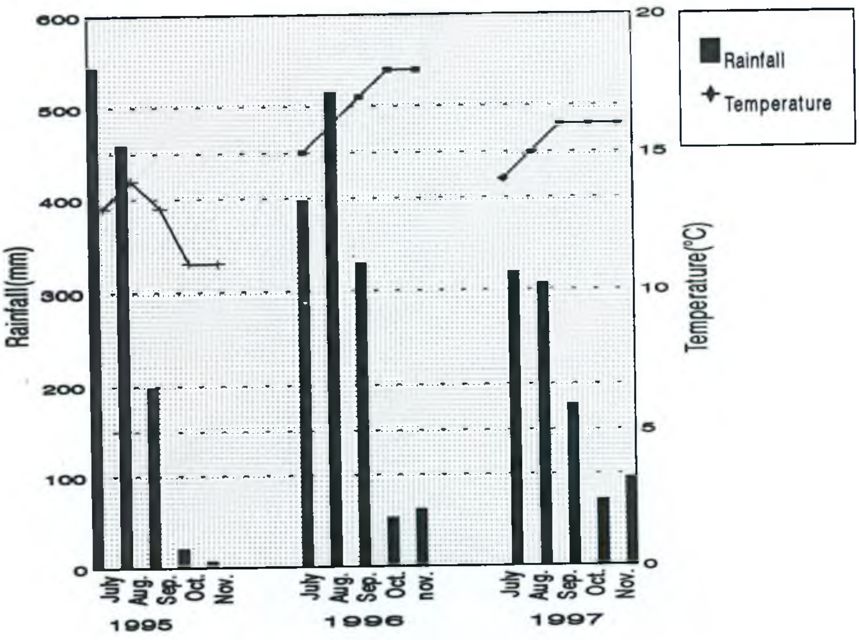

Fig. 1. Weather data of barley growing period of Tikur-Inchini & Shenen districts of West Shewa, 1995 - 1997.

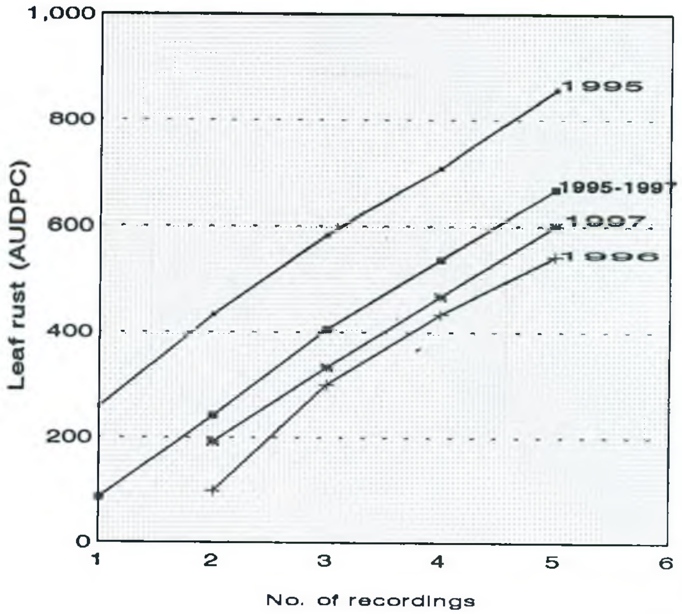

Fig.2. Leaf rust development recorded at ten days interval on the unsprayed plots in Tikur Inchini & Shenen districts of West Shewa, 1995 - 1997.

Table 1. Percent losses in grain yield, thousand kernel weight (TKW), kernel number per spike (KN S^{-1}) and number of productive tillers per plot (NPT^{-1}) of the white seeded local barley variety due to barley leaf rust in Tikur-Inchini and Shenen districts of West Shewa, 1995.

Treatment	Leaf rust severity (AUDPC)	Grain yield (Kg/ha)	TKW (g)	KNS^{-1}	NPT^{-1}
Sprayed	0.0	2193.8	40.8	22.6	216.8
Unsprayed	2841.7	1423.4	30.1	20.7	202.1
Loss (%)	-	35.1	26.2	8.4	6.8
SE	± 654.8	± 69.6	± 1.1	± 0.52	± 6.4
LSD	S	HS	HS	NS	NS
CV (%)	39.9	6.7	5.3	4.2	5.3

Table 2. Percent losses in grain yield, thousand kernel weight (TKW), kernel number per spike (KN S^{-1}) and number of productive tillers (NPT^{-1}) per plot of the white seeded local barley variety due to barley leaf rust in Tikur-Inchini and Shenen districts of West Shewa, 1996.

Treatment	Leaf rust severity (AUDPC)	Grain yield (Kg/ha)	TKW (g)	KNS^{-1}	NPT^{-1}
Sprayed	0.0	1655.7	46.3	19.5	193.0
Unsprayed	1365.0	1345.7	41.4	18.4	190.3
Loss (%)	-	18.7	10.6	5.6	1.4
SE	± 187.1	± 241.5	± 1.8	± 1.2	± 8.9
LSD	S	NS	NS	NS	NS
CV (%)	23.7	27.9	6.9	11.1	8.1

Table 3. Percent losses in grain yield, thousand kernel weight (TKW), kernel number per spike (KN S^{-1}) and number of productive tillers (NPT^{-1}) per plot of the white seeded local barley variety due to barley leaf rust in Tikur-Inchini and Shenen districts of West Shewa, 1997.

Treatment	Leaf rust severity (AUDPC)	Grain yield (Kg/ha)	TKW (g)	KNS^{-1}	NPT^{-1}
Sprayed	0.0	2131.6	42.9	25.8	231.1
Unsprayed	1591.7	1518.2	37.0	24.0	218.2
Loss (%)	-	28.8	13.7	7.0	3.7
SE	± 68.2	± 165.1	± 1.9	± 0.7	± 13.4
LSD	S	NS	NS	NS	NS
CV (%)	7.4	15.7	8.3	4.8	10.3

Table 4. Mean percent losses in grain yield, thousand kernel weight (TKW), kernel number per spike (KN S^{-1}) and number of productive tillers (NPT^{-1}) per plot of the white seeded local barley variety due to barley leaf rust in Tikur-Inchini and Shenen districts of West Shewa, 1995-1997.

Treatment	Leaf rust severity (AUDPC)	Grain yield (Kg/ha)	TKW (g)	KNS^{-1}	NPT^{-1}
Sprayed	0.0	1993.7	43.3	22.7	213.7
Unspraye	1932.8	1429.1	36.1	21.0	203.5
Loss (%)	-	28.3	16.6	7.2	4.8
SE	± 299.7	± 110.2	± 1.2	± 0.45	± 2.44
LSD	S	S	S	NS	NS
CV (%)	26.7	11.1	5.2	3.6	2.0

Discussion

In 1995-1997, there was sufficient rain (967.6 mm - 1354.4 mm) with high number of rainy days (107 - 109) per season. The monthly mean temperatures ranged from 11.1°C - 17.8 °C (Fig 1). This weather condition was favourable for the development of barley leaf rust. Gair et al. (1983) have also reported that barley leaf rust develops from as low as 3°C to as high as 30°C, but urediospore production increases as temperature increases from 10°C to 25°C. The severity of the disease expressed as AUDPC, however varied from season to season depending upon the differences on the appearance of the disease at various growth stages of the crop (Fig 2). In 1995, barley leaf rust infection started at stem elongation and reached a maximum AUDPC of 2841.7 at the end of the growing period. The re-infection of the disease was more and the progress was high because it has infected the crop for a longer time starting from the first appearance (September) until maturity (November). In the second season, although the weather condition was conducive for the development of the disease, infection commenced at the end of the growing period (early November) i.e. at heading to flowering growth stages and hence, the progress of the disease (AUDPC = 1365.0) was the least. In the third year, it came earlier (booting to heading growth stages) than in the second, but later than in the first season. The disease attained an AUDPC of 1591.7. Barley leaf rust is said to survive the harvest period on late green tillers and the fungus then spreads to volunteer barley plants grown at the edges of canals and other ideal areas. Inoculum from such plants serve as a source of initial infection for the coming season's new barley crop (Gair et al. 1983). But, the amount and quality of inoculum being delivered to the crop canopy as well as the time of arrival of inoculum in relation to the stage of the crop's development have significant roll in the epidemic development of the disease (Rasmusson et al. 1985). Since these conditions were not fulfilled at earlier growth stages of the crop, initial barley leaf rust infection delayed and re-infection was less in the second and third seasons. As a result, the disease progress was low in the last two seasons than in 1995. Therefore, the presence of a viable inoculum as well as a susceptible host and conducive environment are the major requirements for a successful infection (Stubbs et al. 1986).

As a result of early infection and high leaf rust development in 1995 season, the amount of yield and yield components loss due to the disease was the maximum. But, in the latter two seasons, the damage was less because the disease infection started at late growth stages. This finding goes in line with the report of Rasmusson et al. (1985) as he stated that the severity of foliar diseases on barley and the amount of yield and quality loss depend on the time of arrival of the inoculum in relation to the stage of the crop's development. Barley leaf rust infection primarily reduces kernel size. So, the losses in grain yield and thousand kernel weight were by far greater than the losses in the number of kernels per spike and number of productive tillers per plot. Melville et al. (1976), also demonstrated that infection at growth stage 5 or later has less influence on kernel number than on the size of kernels. The results we obtained go in line with this finding.

The white seeded local barley variety was severely infected by leaf rust, but tolerated it probably because the pathogen and barley crop have gone through natural selections for centuries. Eshetu (1985) has also reported that Ethiopian landraces are tolerant to rust diseases. Grain yield loss of the white seeded local barley variety with a mean AUDPC of 1932.8 was 28.3% on farmers fields, while the loss of a susceptible barley variety Trompillo with disease progress of AUDPC of 1040.7 on the on-station trial reached 40.2% (Getaneh 1998). Similar yield losses were reported in Canada, Holland and England (Melville et al. 1976).

The study showed that barley leaf rust causes considerable losses on yield and yield components of white seeded local barley variety on farmer's fields. This suggests that there is a need to look into control measures to minimize such losses. Also an effective breeding strategy may be designed to control the disease using resistance.

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