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Barley Net Blotch (*Pyrenophora teres* Drechsl.) Epidemiology and Management

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ABSTRACT

Two experiments were conducted in strip-plot block design during August-December 2002 and April-August 2003 at Sinana, Southeast Oromia, Ethiopia. Vertical factor was 4 varieties of barley and horizontal factor was propiconazole treatment (12+1) and they were replicated four times. The objective of this experiment was to study net blotch epidemiology and management and to suggest the future net blotch control strategy. The level of net blotch epidemic varied by year but its onset was early at GS13, although rainfall was low and temperatures were slightly high in both experimental years. Varieties and treatments affected the course of net blotch development starting from the early stage of the crop. Difference among varieties was substantial starting about 36-44 days after planting. Disease epidemic was significantly influenced by leaf positions, being high in the lower leaves and low in the upper leaves. Net blotch severity was associated negatively with grain yield and 1000-kernel weight starting 36 days after planting. Propiconazole foliar applications at GS30&39 provided greater TKW (4-6%) and grain yield (314.8-560kg / ha) over non-fungicide treatment in present study. Seedling resistance and infected plant debris management as routine activity and propiconazole spray at GS30&39 in seed and malt barley production in severe net blotch development were suggested as future components of barley net blotch disease management strategy.

Key words: *Hordeum vulgare*, Drechslera teres, AUDP

INTRODUCTION

Barley is one of the dominant crops across seven agro-ecological zones with wide ranges of climate and altitude ranging from 1400m to over 4000 meters above seas level (Zemede, 2002) in Ethiopia. Grain production of 9319,063.02 quintals comes from 771,514.54 hectares (Central Statistical Authority, 2001/2002) of land per year per main season. Residue from barley (Girma *et al*, 1996) is an important integral component of animal feed during the dry season.

Barley yield under farmers' condition is 1.2 t/ha, (Central Statistical Authority, 2001/2002) in Ethiopia,. This yield level is lower than worldwide and national yield potential (Berhane, *et al.* 1996) obtained under good managed plots in the country. The low productivity of the crop is associated with multidimensional abiotic and biotic factors. Diseases (Stewart and Dagnatchew, 1967; Eshetu, 1985 and Yitbarek *et al.*, 1996) are the most important limiting factors.

Net blotch, scald and leaf rust are the most three important barley diseases (Yitbarek *et al.*,

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1996) targeted for control. Net blotch had a limited distribution (Eshetu, 1985) before the year 1984 in Ethiopia. To date, this disease is an ever endemic disease to the most parts of the highlands of the country (Yitbarek *et al*., 1996) where barley is important. This disease causes a substantial grain yield loss, 27% on an average and up to 34 % when it is severe (Yitbarek and Wudneh, 1985). On farm average yield loss of 28-29% is accounted for net blotch and leaf rust (Bekele *et al*., 2001) infection

Despite of the wide distribution of the disease in the country, susceptibility of several land race and improved varieties to the disease, and substantial grain yield losses, research on net blotch epidemiology and management is limited. The present experiments were designed to study net blotch epidemiology and management options and to suggest net blotch management strategy.

MATERIALS AND METHODS

Experiments were conducted during August-December 2002, and April-August 2003 at Sinana, Southeast Oromia, Ethiopia. The research site(2400 meters above sea level) represented the high altitude production areas and located at 07¢07N latitude and 40¢10E longitude (Geremew et al., 1998). The experimental area was characterized by acidic clay soil with a pH of 6.3 at the depth of 0-15 cm (Tilahun-personal communication).

Two-rowed malt barley varieties, Beka (susceptible) and Holker (partial resistant) released for production in 1973 and 1979, respectively and two food barley varieties, PGRC/E1694-5 (susceptible), and Ardu-12-60B (moderately resistant) were used. Ardu -12-60B has been in production since 1986 whereas variety PGRC/E1694-5 is a candidate for release. The varieties were row planted by hand at the seeding rate of 100 kg/ha on August 23, 2002 and April, 7, 2003. The preceding crop was bread wheat (*Triticum aestivum*). Fertilizer was applied at the rate of 33/46 N/P_2O_5 kg/ha at planting. Insecticide (Gaucho 70 WP) treated seed at the rate of 250 g 100kgseed^{-1} was used to control barley shoot fly. Weeding was executed once by hand. Twelve combinations of fungicide (propiconazole) treatments at the rate of 125 a.i./ha and non-fungicide treatment were used (Table1). Plots were laid out in strip-plot block design with four replications (Yousfi and Ezzahiri, 2001). Varieties and fungicide applications were assigned to vertical strip and horizontal strip, respectively. A plot size of 2.5m ¥ 2.4m (12 rows at 0.2m spacing) was used. A space of 1.5 and 2.4 meters was left between plots to prevent inter-plot interference. Each plot was also surrounded by guard rows of a single row of wheat variety, K62-95-4a in 2002 and two rows of oat in 2003 at 0.75-cm distance from the border of each plot.

At about 2 weeks after planting, when the second leaf expanded, plots were inoculated with infected leaves & leaf sheaths collected from the preceding year at the rate of 100g/m2. As soon as the initial infection in all plots was observed, debris was removed from all plots.

Agronomic data

At maturity, the four central ($2m^2$) rows were hand harvested at ground level both in 2002 and 2003. Grain yield (g) was recorded. One thousand-kernel weight (TKW) determined in grams on the seed samples taken from four central rows.

Disease assessment

Net blotch severity was scored on the three top leaves: F, unfolded most top leaves, F-1, second most top leaves and F-2, the third most top leaves (Khan, 1987; Robinson and Jalli, 1997; Jayasena *et al*., 2002) at eight-day intervals on 10 randomly selected tillers per plot avoiding the border rows. Leaf, F was the youngest at any stage of the crop the disease noted but unfolded. Disease score has commenced at about crop growth stage

Table 1 Fungicidal (propiconazole) treatments applied at intervals and selected crop growth stages of barley during 2002 August-December and 2003 April –August growing season, to control net blotch at Sinana, Southeastern Oromia, Ethiopia.

Treatment	Spray schedule	Spray timing	Spray frequency per year	
			2002	2003
1	7 day interval	-	11	14
2	14 day interval	-	6	7
3	21 day interval	-	4	5
4	28 day interval	-	3	4
5	35 day interval	-	3	4
6	*GS30	Early	1	1
7	GS39	Mid	1	1
8	GS59	Late	1	1
9	GS30&39	Early &mid	2	2
10	GS30&59	Early & late	2	2
11	GS39&59	mid &late	2	2
12	GS30.39&59	Early, mid & late	3	3
13	Non fungicide	-	-	-

* Crop growth stage according Zadoks et al., (1974)

of GS13 according Zadoks *et al.* (1974), 28 days after planting. Net blotch severity was taken by using keys of Hampton and Arnst (1978). Area under disease progress curve (AUDPCs) were determined for each leaf position according to Shanner and Finney (1977). Then, standardized area under disease progress was obtained according to Campbell and Madden (1990) and was used in analysis.

Disease severity noted on F, F-1 and F-2 leaves position were transformed by using the logistic transformation (Vander Plank, 1963) of the form logit y = ln (y/1-y) in order to linearize the disease percentage. Then, simple linear regression applied to the transformed data values and the slopes of regression lines, infection rate were obtained (Plaut and Berger,1981). This infection rate was evaluated against experimental factors studied.

Analysis of variance (ANOVA) was conducted for standardized AUDPC, grain yield (kg/ha) and TKW(g). Correlations between severity and yield and TKW were made.

RESULTS

Year effects on the net blotch progress

In both year 2002 represented by August to December, and year 2003 represented by April to August growing seasons, net blotch symptom appeared early at the crop stage(GS13) in most of the plots with very low level of severity.

The years, 2002 (251.9-mm rainfall) and 2003(252.5-mm rainfall) were dry as compared with average rainfall of the last eleven years . Both maximum and minimum temperatures were higher than the means of the specific month of the last eleven years of the growing season irrespective the experimental years (data not shown).

Effects of variety on the net blotch progress

Varieties affected significantly the net blotch severity development in time. The significant effects of variety on the course of net blotch development started early although the substantial difference between variety PGRC/E1694-5 and the rest of varieties in both experimental years was apparent after 36-44 days after planting (Figure1). Moreover varieties responded differently under different disease pressure as shown by interactions between treatment and variety (P= 0.0001 in 2002&2003). The differences among varieties generated variable levels of area under disease progress curves (Figure 1 and Table 2). The curves represent, almost, sigmoid type a curve common to most foliar diseases (Figure 1). Food barley variety PGRE/E 1694-5 allowed faster disease progression followed by Beka. Despite this clear difference among them (Figure 1), AUDPC values in 2002 were not significantly different for Ardu-12-60B, Holker and Beka at $P \leq 0.05$. Both susceptible malt and food barley varieties were not significantly different in 2003 by AUDPC. Moderately resistant variety, Ardu-12-60B sustained the least AUDPC followed by partially resistant variety Holker in the year 2003. An average percentage of AUDPC reduction due to Ardu-12-60B was in the ranges of 13-41.08, 49.9-60.98, and 14.6-61.39 % over Holker, PGRC/E1694-5 and Beka, respectively (Table 4). The rate of net development on Ardu-12-60B was revealed low (data not shown) as compared to the rest varieties.

Effects of leaf position on the net blotch progress

Net blotch epidemic varied by leaf positions within the most top three leaves in terms of area under disease progress (Table 2). The disease showed a trend of decreasing from lower to upper leaves (Figure 1 and Table 2). The rate of disease progress was higher on the leaves, F-2 than those on two upper most leaves, F and F-1 (data not shown).

Varieties by leaf interaction had a significant effect (P=0.0001) on net blotch development. This interaction was explained by the increasing of an area under disease progress curve values from leaf F to F-2 being consistently higher in PGRC/E 1694-5 in both years except on leaf F-2 in year 2003 and lower on the third leaf of Ardu-12-60B.

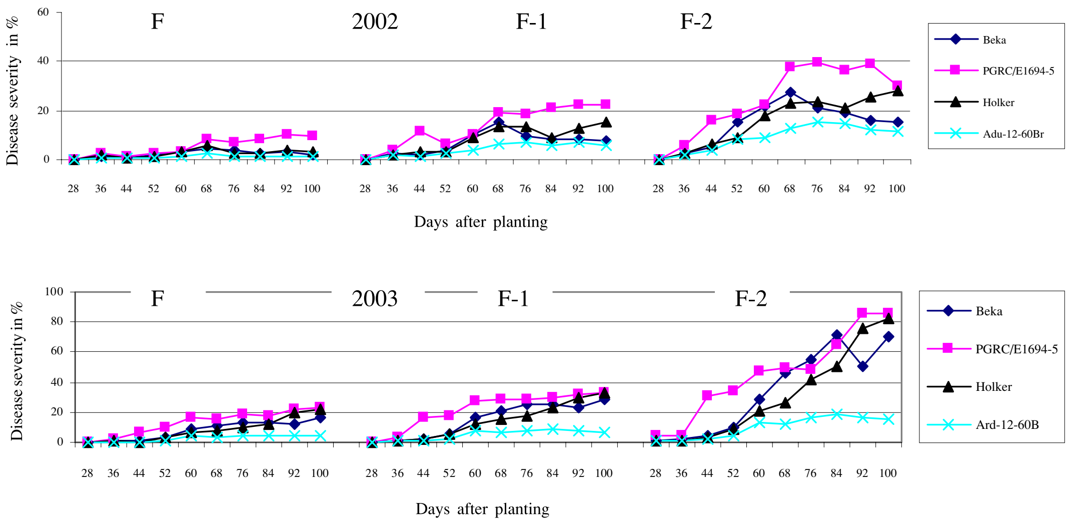

Figure 1 Disease progress curves on upper leaf (F), second most upper leaf (F-1) and third most upper leaf (F-2) in year 2002 and 2003, Sinana, Southeastern Oromia, Ethiopia.

Table 2 Net blotch development (AUDPC) within three most upper leaves in barley, 2002-2003, Sinana, southeastern, Oromia, Ethiopia.

Year	Leaf position	AUDPC[1] by variety			
		Beka	PGRC/E1694-5	Holker	Ardu-12-60B
2002	F	1.6931c	2.7853c	1.4805c	1.8016c
	F-1	4.5087b	7.6542b	4.5620b	4.1053b
	F-2	9.1010a	15.6422a	9.1452a	7.1610a
Mean		5.1010b	8.6940a	5.0630b	4.3560b
2003	F	9.3382c	9.3018c	6.1116c	3.8733c
	F-1	16.1942b	17.0486b	12.0853b	6.7598b
	F-2	35.6549a	34.1879a	21.8922a	13.1807a
Mean		20.393a	20.181a	13.364b	7.938c

Values in each column for leaf position and variety means in rows followed by the same letters per year are not significantly different at P£0.05

[1] = standardized area under disease progress curves. F = unfolded most top leaf, F-1= second most top leaf, F-2= third most top leaf (leaf below F-1).

Net blotch severity and yield and yield component relations

Net blotch severity with grain yield and TKW were correlated negatively starting from as early as 36 days after planting (data not presented).

Effects of fungicidal treatment on the epidemiological factors

Year 2002

The difference between fungicidal treatments for disease severity at each disease noting date after planting (DAP) data not presented and AUDPC were significant (P=0.0001) except at 28,36, 44 DAP in the most top leaf (F); at 28, 44 and in F-1, and at 28 DAP in F-2.

Fungicide applications reduced mean net blotch AUDPC over non-fungicide treatment, 19.86–84.81% in Beka, 15.93-83.22% in PGRC/E 1694-5, 11.38–81.15 % in Holker and 34.32 –77.18% in Ardu-12- 60B (Table 3). Treatment 1 (Table1), 11 times propiconazole application at 7 days interval starting from the onset of net blotch gave the highest net blotch control in all varieties. Treatments 2,3,4, 9 and 12 were not significantly different from one another in Beka, PGRC/E1694-5 and Holker and ranked second after treatment 1. Treatments 6 and 10 were not also significantly different from these treatments in varieties Beka and Holker. In Ardu-12-60B, treatments 2,3,4 and 12 were the second best treatments without significant differences among them. Treatment 8 was less effective across varieties and also did not differ from non-fungicide treatment in Holker. Among single applications, treatment 6 performed better in Beka, Holker, and Ardu-12-60B whereas treatments 6 and 7 were not significantly different in variety PGRCE/E1694-5 (Table 6).

Year 2003

Net blotch control over non-fungicide applied treatment ranged from 7.94-83.82% in Beka, 5.75–77.53% in PGRC/E 1694-5, 3.73 –77.48 % in Holker and 11.58–75.89% in Ardu-12-60B. Treatment 1 (Table1) significantly reduced AUDPC over treatments studied (Table 4).

Table 3 Effects of fungicide treatment on barley net blotch area under disease progress curves (AUDPC) applied at intervals and selected crop growth stage on four varieties, 2002, August - Dec, Sinana, South Eastern Oromia, Ethiopia.

Treatment nt	AUDPC[1]								
	Variety				Mean	Control over non-fungicide treatment (%)			
	Beka	PGRC/ E1694-5	Holker	Ardu-12- 60B		Beka	PGRC/ E1694-5	Holker	Ardu-12- 60B
1	1.5644e	2.5f	1.8763d	2.0149f	1.9888I	84.81	83.22	81.15	77.18
2	3.4242d	6.288e	3.2279c	3.1958e	4.0340 h	66.74	57.79	67.56	63.81
3	3.2269d	5.663e	3.1438c	2.5035ef	3.6343 h	68.66	61.98	68.41	71.65
4	4.0080d	7.6de	4.2083c	3.239e	4.7639 g	61.07	48.98	57.71	63.32
5	6.9023c	10.698bc	6.7767b	5.5878b	7.4912 c	32.97	28.18	31.90	36.72
6	4.4477d	10.713bc	3.9213c	4.2865cd	5.8420 e	56.80	28.08	60.60	51.45
7	6.3042c	9.012cd	6.4338b	5.0514bc	6.7003 d	38.77	39.50	35.35	42.79
8	8.2519b	12.523b	8.8196a	5.7997b	8.8486 b	19.86	15.93	11.38	34.32
9	3.8716d	7.796de	3.6346c	4.2302d	4.8831 f g	62.40	47.66	63.48	52.09
10	4.1386d	9.778cd	4.095c	4.0292d	5.5101 ef	59.81	34.36	58.85	54.37
11	6.7455c	9.055cd	6.8188b	4.674cd	6.8232 cd	34.49	39.21	31.48	47.07
12	3.1307d	6.499e	2.9058cd	3.1858e	3.9303 h	69.59	56.37	70.80	63.92
13	10.2966a	14.896a	9.9517a	8.8299a	10.9936 a	0	0	0	0
CV(%)	29.4	29.4	29.4	29.4	53				

Means in the column and followed by the same letters are not significantly different at P£0.05
[1]= standardized area under disease progress curves (AUDPC).

Treatment 2 reduced the AUDPC by 63 % in Beka, 41% in PGRC/E1694-5 and 61% in Holker. AUDPC reduced in treatments 2 and 3 by 47 and 42%, over non-fungicide treatments respectively in variety Ardu-12-60B and ranked the second best treatments after treatment 1. The treatments 3,6,9,10,12; 7,8, treatments 11,13 in PGRC/E1694-5, treatment 4,5,10; 6,7,9,10, 12 in Beka, treatments 3,5,7,9; 6,10,11 in Holker and treatments 4,5,7, 8,9,11,12 in Ardu-12-60B did not significantly differ from net blotch control (Table 4). However, over all fungicidal treatment means (Table 4) made clear that treatments 9 and 12 were more effective than double spray treatments and single spray treatments in both years after treatments 1-4. The values of infection rate were lower in plots received fungicide applications than in non-fungicide treatments except treatments 6 and 10 in F-1 or F-2 in variety PGRC/E 1694-5 in 2002 (data not showa). Data for 2003 is presented in Figure 2. Of treatments with low frequencies, treatments 9 & 12 had most inhibited net blotch infection rates across varieties and years.

Experimental factors influencing yield and yield components

The differences between treatments were significant at P= 0.0001 for grain yield and 1000-kernel weight (TKW) in both experimental years. Treatments x variety interactions were absent ($P < 0.05$) for agronomic parameters in both experimental years except for TKW in 2003.

TKW increment due to fungicide applications ranged from 1.14-9.86% in year 2002 and from 2.3-17.03% in year 2003 over non-fungicide treatment(Table 5). Treatments 1-4, 9-

Table 4 Effects of foliar fungicide application on barley net blotch applied at frequent intervals and selected crop growth stage on four varieties, 2003, August - Dec, Sinana, South Eastern Oromia, Ethiopia

Treatment	AUDPC[1]								
	Variety				Mean	Control over non-fungicide treatment(%)			
	Beka	PGRC/ E1694-5	Holker	Ardu-12-60B		Beka	PGRC/ E1694-5	Holker	Ardu-12-60B
1	4.423g	6.069g	4.254f	2.6593g	4.3514g	83.82	77.53	77.48	75.89
2	10.099f	15.96f	7.342e	5.8147f	9.8038f	63.06	40.90	61.13	47.29
3	15.865e	19.656de	10.475d	6.3433ef	13.0846e	41.97	27.22	44.55	42.49
4	20.135d	21.815cd	13.683c	7.2045de	15.7092d	26.35	19.22	27.57	34.69
5	20.335d	21.452cd	12.687cd	7.4263de	15.4751d	25.62	20.57	32.84	32.68
6	24.013bc	20.155de	16.68ab	9.316b	17.5329c	12.17	25.37	11.70	15.55
7	23.895bc	24.51b	13.155cd	8.6606bc	17.5551c	12.60	9.25	30.36	21.49
8	25.17ab	23.444b	18.187a	9.3362b	19.034b	7.94	13.19	3.73	15.36
9	23.746bc	18.174ef	13.161cd	8.9253bc	16.0016d	13.15	32.71	30.33	19.09
10	21.648cd	19.819de	16.513bc	7.7994cd	19.0944d	20.82	26.62	12.59	29.29
11	25.06ab	25.453ab	16.513ab	9.7529b	19.1946b	8.34	5.75	12.59	11.58
12	23.416bc	18.819e	13.584c	8.924bc	16.1859d	14.35	30.32	28.09	19.10
13	27.34a	27.007a	18.891a	11.0308a	21.0671a	0	0	0	0
CV(%)	14.17	14.7	14.17	14.7	40				

Means in the column and followed by the same letters are not significantly different at P≤0.05
1= standardized area under disease progress curves(AUDPC).

12 gave significant seed weights over non-fungicide treatment in year 2002. Treatment 1 improved seed weight by 9.87 in 2002. Treatments 6,7 and 8, single applications, were not significantly better than non-fungicide treatment in 2002 for seed weight. All treatments significantly improved seed weight over non fungicide treatment in 2003. The seed weight increments obtained due to treatments 1-3 were consistent across test years. Treatment 9, double applications, although exceeded by multiple fungicide applications treatments1-3 in 2002 and 1-4 in 2003, gave the second better kernel weights (4-6%) across years.

Grain yield was improved by 7.3-52.95 % in 2002 and by 8.82-77.58% over non-fungicide treatment. Treatment 1 gave the highest grain yield (2448.8-3787.91kg/ha) in both years.

The intervention of net blotch development by double sprays at GS30&39 consistently yielded 23% over the non-fungicide treatments (Table 6). This yield not significantly differ from the grain yields obtained from treatment 3,4,12 in 2002 and 2-4, 10 and 12 in 2003. Single fungicide applications contributed the least to the grain yield.

DISCUSSIONS

The disease symptom was apparent at GS 13 in both experimental years. However, disease severity was variable between August to December, 2002 and April to August 2003. Net blotch was moderate in 2002 and to high in 2003 although low rainfall and slightly higher temperatures were prevailed in both years as compared with long-term precipitation and temperatures. This could be attributed to the dew development over night and

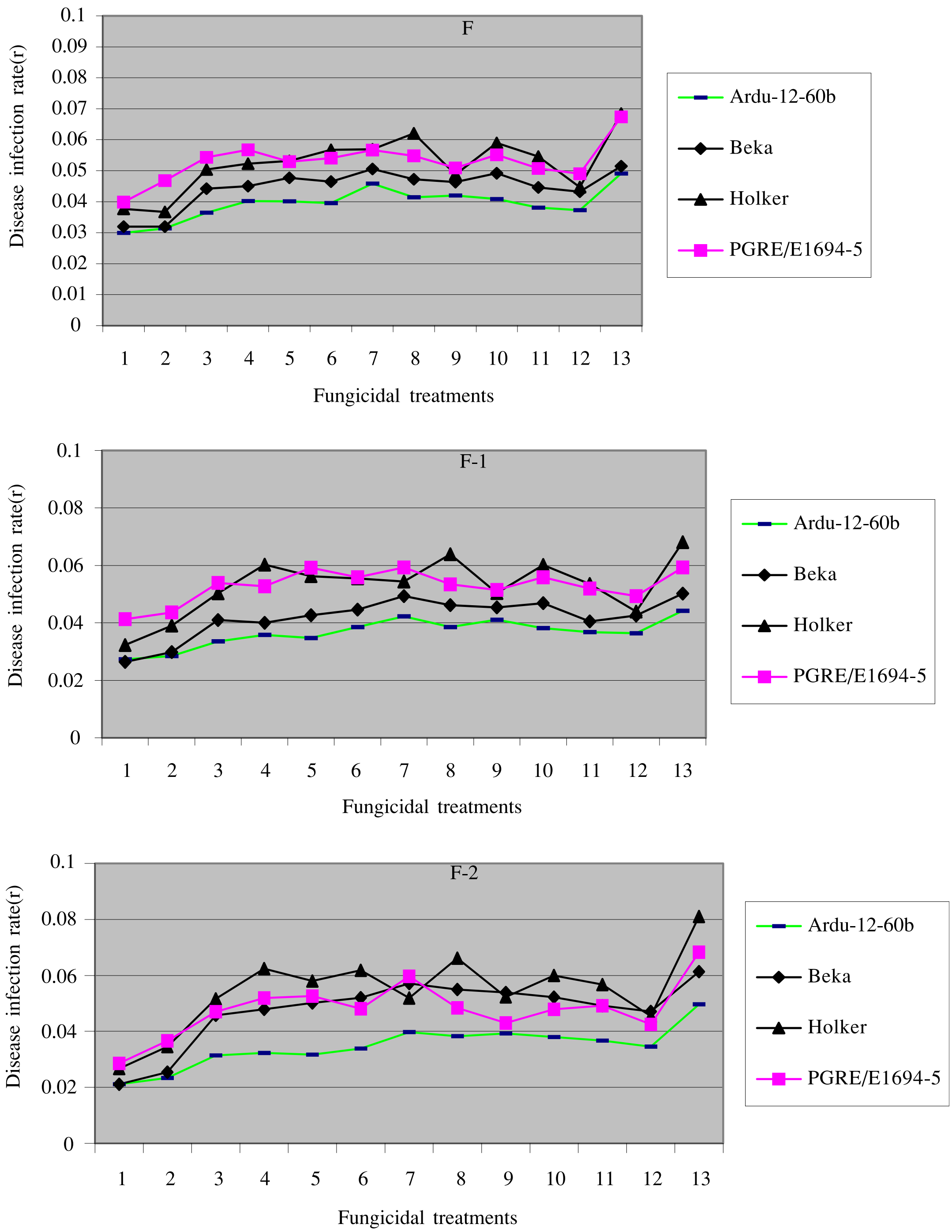

Figure 2 Effects of fungicide treatment on the net blotch infection rate in upper leaf (F), second most upper leaf (F-1) and third most upper leaf (F-2) in four barley varieties in 2003, Southeastern Oromia, Ethiopia.

Table 5 Effects of fungicide (Propiconazole) treatment applied at intervals and selected crop growth stages on 1000kernel weight (TKW) of barley affected by net blotch, during 2002 (August-December) and 2003 (April –August) growing season, Sinana South Eastern Oromia, Ethiopia.

Treatment	Spray schedule	Spray timing	TKW			
			In gram		% gain over non-fungicide treatment	
			2002	2003	2002	2003
1	7 day intervals	-	41.4093a	39.4693a	109.86	117.03
2	14 day intervals	-	40.4114b	37.1794b	107.21	110.24
3	21 day intervals	-	39.8256bc	35.9633cd	105.66	106.63
4	28 day intervals	-	39.1603cde	36.4014bc	103.89	107.93
5	35 day intervals	-	38.5973def	35.2726cd	102.40	104.58
6	*GS30	Early	38.1215ef	34.81d	101.14	103.21
7	GS39	mid	38.1860def	35.2996cd	101.31	104.66
8	GS59	Late	38.2958def	34.8971d	101.60	103.47
9	GS30&39	Early &mid	39.2866cd	35.8208cd	104.23	106.21
10	GS30&59	Early & late	39.0884cde	35.4993cd	103.70	105.26
11	GS39&59	mid &late	38.8736cde	35.1593d	103.13	104.25
12	GS30.39&59	Early, mid & late	38.7286def	35.3864cd	102.75	104.92
13	Non fungicide treatment	-	37.6934f	33.7264e	100.00	100.00
CV(%)			3.82	4.29		

Means in each column and followed by the same letters are not significantly different at P£0.05

* Signifies crop stage according to Zadoks *et al.* (1974)

up to 8:00 a.m morning. The situation underwhich the net blotch developed and the disease level obtained in 2002 and 2003 clearly suggested the possibility of net blotch disease of becoming a severe disease in areas where low to high rainfall and cooler and humid environments prevailed in Ethiopia. According Plaut and Berger (1981), Rouse *et al.* (1981) and Sutton and Steel (1983) rate of disease increase was also the greatest for epidemic starting from the lowest initial disease severity.

An early onset of the disease and rapid development from lower leaves to upper leaves might enable the net blotch disease to be a single dominant disease in both years (seasons). Moreover, the fact that net blotch beginning with low infection and increasing downwards, from F to F-2 leaves positions in time makes clear that the lower leaves remains an important epidemiological factor in barley net blotch pathosystem in Ethiopia.

The net blotch damaging potential is high in Ethiopia. This was revealed by the advantages obtained due to repeated fungicide application over non-fungicide treatments in both 2002 and 2003 (Tables 5 and 6) and negative association between net blotch severity with grain yield and TKW starting as early as 36 days after planting across years and varieties. This also suggested that the detrimental effects of net blotch started from the very early stages of the crop.

Thus, delaying the lower leave infection by delaying the inoculum through possible means seems sound strategy for net blotch management.

Inclusion of an early net blotch management strategy as one of components of barley disease management is relevant for Ethiopia due to reasons

Table 6 Effects of fungicide (Propiconazole) treatment applied at intervals and selected crop growth stages on grain yield of barley affected by net blotch, during 2002 (August-December) and 2003 (April –August) growing season, Sinana, South Eastern Oromia, Ethiopia.

Treatment	Spray schedule	Spray timing	Grain yield			
			Kg/ha		% gain over non-fungicide treatment	
			2002	2003	2002	2003
1	7 day intervals	-	3787.91a	2448.8a	152.95	177.58
2	14 day intervals	-	3307.53b	1903.9b	133.56	138.06
3	21 day intervals	-	2915.89cd	1692.9bc	117.74	122.76
4	28 day intervals	-	2858.87cde	1760.5bc	115.44	127.67
5	35 day intervals	-	2690.95e	1521cd	108.66	110.30
6	*GS30	Early	2657.28ef	1564.7cd	107.30	113.47
7	GS39	Mid	2679.92e	1500.6cd	108.21	108.82
8	GS59	Late	2404.74g	1599.6cd	97.10	116.00
9	GS30&39	Early &mid	3036.77c	1693.8bc	122.62	122.83
10	GS30&59	Early & late	2831.28de	1653.5bc	114.32	119.91
11	GS39&59	mid &late	2791.62de	1575.7cd	112.72	114.26
12	GS30.39&59	Early, mid & late	3048.64c	1719.1bc	123.10	124.66
13	Non- fungicide treatment	-	2476.53fg	1379d	100.00	100.00
CV(%)			7.83	25.95		

Values in each column followed by the same letters are not significantly different at P£0.05
*Signifies crop stage according Zadoks et al., (1974)

discussed above and below. In many parts of Ethiopia where this disease was reported, barley production once in a year was a minimum practice. This practice attributed to substantial infected crop residues left in the field after harvest, a substantial inoculum source for the early disease epidemics in the next crop. According to Mathre (1982) and Sheridan and Grbavac (1985) the infected crop residue attributed to the net blotch epidemics rather than seed which was the most effective in disseminating the disease from field to field (Arnst *et al.*, 1978; Mathre, 1982).

Initial net blotch management could be achieved in Ethiopia by infected crop residue management through its effective removal from the field, crop rotation and timely turn over of infected crop residues. Previous research results showed that the risk of leaf diseases on barley reduced when barley followed *Triticum aestivum*, *Crambe abyssinica, Brassica napus*, *Pisum sativum* (Krupinsky *et al.*, 2004). Cultural practices are location specific compared with chemicals, thus, effects of various precursor crop on the net blotch development and yield must be further explored and used for this disease management in Ethiopia.

Varietal seedling resistance was another option for curtailing the initial epidemics as demonstrated by variety Ardu-12-60B in contrast to variety PGRC/E1694-5. The effect of variety Ardu-12-60B on the course of disease progress was substantial until 100 days after planting which could be attributed to the resistance as confirmed by relatively low AUDPC values and infection rates. Thus, seedling resistance sources from Ardu-12-60B and other sources could be exploited in barley breeding program for curtailing the initial net blotch epidemic such as developed on variety PGRC/E1694-5.

The gap between most frequently treated and untreated treatments suggested that quantitative resistance of varieties PGRC/E1694-5, Beka and Holker were not enough for effective net blotch management (Figure 1). Ardu-12-60B was a late maturing and required high amount of rainfall for longer period for reaching full maturity. The rainfall deficit encountered in both years and higher level of net blotch appeared late in the seasons had significant effect on this variety.

Cultural control measures might not guarantee the absence of net blotch epidemics in farmers fields since the inoculum could be moved by wind among neighboring fields. Because of the polycyclic nature of the pathogen, little amount of inoculum could enable the disease to reach a high level of epidemic under favorable conditions. Under such condition, fungicide interventions could control the disease and increase yield components and yield. Treatments included in this study increased seed weight and grain yield indicating that net blotch affected grain yield by affecting seed weight. These results were in line with the results of Jordan (1981), Sutton and Steel (1983), Hims (1987), Khan (1987), Martin and Sanderson (1988), Entz *et al.* (1990), Priestley and Bayles (1982), Riesen and Close (1987). Treatments 1- 4, 9 and 12 gave better TKW and grain yields in this order. However, the environmental reasons may not allow applying fungicide more than two times in cereals. Moreover peasants in Ethiopia have been usually reluctant to include fungicide as one of disease control measures in highland cereals, as they are concerned about fungicides cost. Further testing on low rates of effective treatment and yield improvement of variety could alleviate this problem. However the positive effect of propiconazole is not limited only to net blotch reduction and better yield of current year but increases number of large seeds (Entz *et al.*, 1990) which significantly contributes to barely yield potential (Entz *et al.*, 1990; Spilde, 1989) of the next crop. Propiconazole application at GS30 and GS39 gave higher grain yield over the other double and single treatments mainly by influencing seed weight, thus seed size, although this was not considered in the study. Thus, propiconazole application at GS30 and GS39 could be feasible in seed production and malt barley grain in Ethiopia where the net blotch remains severe.

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