Barley Yield-Loss Due to Net Blotch and Leaf Rust in Bale Highlands

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Abstract

A yield loss study on barley due to net blotch and leaf rust was conducted in '*meher*' (August-December) season from 1996-1997 and in '*belg*' (March-July) season in 1997 and 1998. Sprayed (broad spectrum-systemic fungicide) and unsprayed treatments were used in nine farmers' fields in each experimental year. Fungicides were applied two to three times at 15-25 days intervals starting from on-set of disease symptoms. The difference in disease severity between fungicide sprayed and unsprayed treatments for both leaf rust and net blotch was significant. Losses in grain yield, straw yield and thousand-grain weight were calculated as the difference between sprayed and unsprayed treatments. Grain yield loss ranged from 20 to 35% in *meher* season with the mean of 28% and from 25 to 33% in *belg* season with an average of 29%. The total straw yield loss varied from 19-40% in *meher* season and from 13-31 % in *belg* season. Likewise, straw for direct animal feed (total straw yield - loss in field) was reduced by 19-40% in *meher* season and by 13 -31% in *belg* season with corresponding average of 29% and 22%. Similarly, 11% and 2-14% loss of thousand-grain weight was observed in *belg* and *meher* seasons, respectively. The magnitude of grain, straw and thousand kernel weight losses recorded under farmers' circumstances confirmed that net blotch and leaf rust are important barley diseases in the bimodal rainfall areas of Bale highlands. Fungicide application has provided a marginal rate of return of 50.9% in *meher* season. However, regardless of effective disease control and yield advantage gained from cultivar Arusso, grain yield remained low under both seasons. Thus, developing resistant and high yielding cultivars and effective means of control against net blotch and leaf rust needs emphasis in Bale highlands.

Introduction

Disease surveys in Bale and at the national level (Eshetu, 1985; Yitbarek et al, 1996) have identified net blotch caused by *Pyrenophora teres* Drechs and leaf rust caused by *Puccinia hordei* Otth as major threats to barley production. Yield losses incurred by each disease have been found variable depending how and where the disease has been occured (Eshetu, 1985; Yitbarek et. al, 1996; Getaneh, 1998).

Barley diseases infect the crop simultaneously, but with different intensity. Yield losses so far set in Ethiopia for net blotch and leaf rust on barley have been generated on individual basis except in one case where grain yield and thousand kernel weight losses were reported for net blotch and scald (Yitbarek et. al, 1996). Yield loss studies so far carried out were done on research station and state farms, under maximum external input environments, using susceptible cultivars that were hardly grown by subsistence farmers. Yield loss studies due to barley net blotch and leaf rust was conducted in on-farm in 1996 and 1997 in '*meher*' and in 1997 and 1998 in '*belg*' seasons.

The study was carried out under subsistence farmers' conditions using widely cultivated local cultivar (Arusso) in erratic bimodal rainfall areas of Bale. This paper describes the result obtained from this study.

Materials and Methods

During 1996-1997 *meher* and 1997-1998 *belg* seasons, fungicide sprayed and unsprayed treatments were super-imposed on nine farmers' fields planted to a variety Arusso. Fields from Sinana, Agarfa, Gassera and Dinsho were randomly selected during each test season. Farmers' fields were used as replications. The plot size of the experiment was 5mx5m with harvested plot size of 4mx4m.

Frequency of land preparation and fertilizer application (Bekele et al 1998; Almayehu & Franzel 1987) were variable depending on farmers interest. Seeds of barley were sown using broadcasting method, following farmers' practice. Fungicide applications started from on-set of either net blotch or leaf rust or both. Depending on their availability, Cyproconazole (Alto 100SL) at 0.4 liters product per hectare or Propiconazole (Tilt 250 EC) at 0.5 liters product per hectare was applied 2-3 times to the sprayed plots. Fungicide applications were repeated at an interval of 15-25 days. To avoid fungicide drift space of 3m was left between sprayed and unsprayed plots.

Terminal disease severity of net blotch and leaf rust was taken in percent on the whole plot about 20 days after the final spray. The disease severity was log $(x+1)$ transformed and used in statistical analysis. The crop was harvested at ground level when it was dry enough for immediate threshing just after harvest. Total straw yields was estimated by subtracting grain yield from biomass. Straw yields for direct animal feed was determined as 0.7kg/kg of total straw yields. The remaining 0.3kg/kg straw yield have been removed from sprayed and unsprayed treatments for analysis of field loss (Girma et. al 1996) during threshing and other process in the field. Percent crop losses due to diseases were calculated from grain yield, straw yield, and thousand kernel weight of sprayed and unsprayed treatments. Marginal rate of return has been calculated by using average producers' price of 95 Ethiopia Birr (EB)/100kg grain for Bale zone (CSA, 1998) and Propiconazole current price of 156.68 EB/l which is comparable to the price of Cyproconazole (Sinana state farm price) and spray cost.

Results

Leaf Rust Occurrence and Relation with Agronomic Parameters

Leaf rust occurred both in 1996 and 1997 *meher* and in 1998 *belg* seasons. Differences in disease severity between treated and untreated plot in both *belg* and *meher* seasons were significant. However, in *meher*, disease development was higher in 1996 than 1997 (Table 2). For *belg*, rust occurred only in 1998 and good control level was attained as well.

Despite lower severity level observed across years as compared to net blotch, leaf rust was negatively and significantly ($p<0.05$) associated with grain yield ($r = -0.282$), straw yield ($r = -0.254$) and biomass ($r = -0.283$). Leaf rust was also negatively and significantly ($p<0.01$) associated with thousand kernel weight in *meher* 1997 ($r = -0.60$) and *belg* 1998 ($r = -0.878$). In *meher* 1996 negative association was observed, but the relation was not significant.

Net Blotch Occurrence and Relation with Agronomic Parameters

Net blotch had occurred throughout the test seasons. However, severity of the disease pressure varies between and within the seasons. Difference between sprayed and unsprayed plot was significant in two *meher* and two *belg* seasons. For the *meher* season, disease severity in 1997 was more than double than that of 1996 (Table 2).

The association between net blotch severity and thousand kernel weight was negative and significant in *meher* seasons of 1996 (r -0.574, $p<0.05$) but negative and non-significant in *meher* 1997 ($r = -0.116$) and *belg* 1998 ($r = -0.275$).

Losses

Grain yield

Grain yield difference between sprayed and unsprayed treatment was significant in all cases. During the *meher* season the grain yield difference was 353 kg/ha (20.3% loss) in1996 and 507.8 kg/ha (35.4% loss) in1997 (Tables 1&2). For the *belg* season, the yield difference was 342.5 kg/ha (25.2% loss) and 398.2 kg/ha (32.74% loss) in 1997 and 1998, respectively. The average grain yield loss for *meher* was 28% (430 kg/ha) and for *belg* 29% (370 kg/ha). On average, grain yield to biomass ratio increased from 1.92 - 3.19% in protected plots over unprotected plots during the *belg* season (Table 1). In *meher*, however, the ratio increased only slightly (0.34%) in 1996 and decreased in 1997.

Total and available straw yield

Straw yield difference between sprayed and unsprayed treatment throughout the experimental period was significant. A total straw yield difference between sprayed and unsprayed plot in *meher* seasons of 1996 and 1997 was 559.5 kg/ha (19.1% loss) and 1605.1kg/ha (39.6% loss), respectively. During the *belg* season, straw yield difference between sprayed and unsprayed plot was 383.1 kg/ha (12.8% loss) in 1997 while in 1998 the difference was 730.2 kg/ha (30.9% loss). Thus, the average straw yield loss was 1082 kg/ha (29% loss) in *meher* and 557 kg/ha (21% loss) in *belg* (Tables 1 and 2). During *meher* 1996 and 1997, reduction of available straw (to animals feed) was 391.6 and 1123 kg/ha respectively. Available straw reduction of 268.2 and 511.2 kg/ha was observed in *belg* 1997 and 1998, respectively.

Plant height and thousand kernel weight

Generally plants in sprayed plots were significantly taller than unsprayed plots except in *meher* 1996. Plant height has increased from 3 to 5% in *meher* seasons and from 6 to 11% in *belg* seasons due to net blotch and leaf rust protection. The overall average increment in plant height was 4 % in *meher* and 8% in *belg* seasons (Tables 1 and 2). Difference of 2 to 14% in *meher* and 11% in *belg* seasons was observed in thousand-kernel weight between sprayed and unsprayed treatment (Tables 1 and 2).

Economic analysis

Grain and straw yield, the principal constituent of economic benefit to the farmer, were significantly affected by fungicide application. On the average grain yield advantage of 370 kg/ha and 430 kg/ha were respectively attained in *belg* and *meher* seasons due to leaf rust and net blotch protection by fungicides. The total cost of the fungicide on the average was 271.02 birr/ha. A simple calculation will show that the total benefit obtained in these cases will be 80.8 birr/ha in *belg* season and 137.9 birr/ha in *meher* season. Furthermore, 29.8% and 50.9% MRR was gained in *belg* and *meher* respectively due to fungicide application (Table 3).

Discussion

Disease severity and agronomic parameters varied between and within *meher* and *belg* seasons. The variations could be attributed mainly due to environmental factors. Early on set of the rain and higher rain fall with gradual decrease late in the season was very ideal for the crop hence highest yield was observed both from sprayed and unsprayed treatment during *meher* 1996 (Fig 1). Kiesling (1985) explained that severity of foliar barely diseases depend largely on pathogen quality (virulence and aggressiveness), resistance of cultivar, wet period, time of inoculum arrival and stage of the crop combined with high humidity and optimum temperature. Subsequently, so do the amount of yield and quality loss. However, with all variation observed within both seasons, on average, more grain yield, straw yield, thousand kernel weight and taller plants were observed in *meher* seasons than in *belg* seasons suggesting better suitability of *meher* season for the local cultivar.

Leaf rust (often with less severity than net blotch) has co-occurred with net blotch across all test years except in 1997 *belg* season (Fig 2). Lower minimum and maximum temperature during *belg* 1997 may inhibit development of rust pathogen, and extremely high rainfall received during early in this season may have also contributed by washing the initial inoculums. Simultaneous rise both in minimum and maximum temperature in 1998 (Fig 4)might have created higher humidity and free moisture that resulted in severe leaf rust in *belg*, 1998 (Table 1). High rainfall that was coupled with lower average temperature of 14.4 C than the optimum temperature of 15-25C (Mathre, 1982) has probably disfavored development of net blotch in *meher*, 1996 (fig 3). While warmer *meher* nights and cooler days of 1997 may have caused good blotch development. Good net blotch development coupled with rust caused significant difference between sprayed and un sprayed treatment in all agronomic traits (grain yield, straw yield, thousand kernel weight and plant height) (Table 2).

Grain yield that was obtained from Arusso by protecting from net blotch and leaf rust in this study was lower than yield of improved cultivars (such as HB - 42 and ARDU – 12 – 60B) reported by Berhane et al (1996). Unfortunately, these improved varieties couldn't be grown in bimodal rainfall areas due to barley shoot fly damage. This shows improving yield potential of Arusso is essential in addition to good net blotch and leaf rust management.

Fungicides, Cyproconazole and Propiconazole, gave comparable efficacy against net blotch and leaf rust where ever they have been used. Moreover, Sutton & Steele (1983) and Steffenson et al (1991) reported that Propiconazole delays the senescence of leaves, and extend the duration of green leaf tissue with out significantly affecting yield and yield components. Thus, significant grain, straw yield and thousand kernel weight yield advantage observed across years and seasons (Tables 1 &2) was attributed to net blotch and leaf rust protection, unless cyproconazole might had some effect on the crop that may not have been related to disease control

Control of net blotch and leaf rust saved a significant amount of biological yield. This was most probably due to the presence of active photosynthetic areas and delaying the senescence of the crop that has in turn promoted more accumulation of grain yield, straw yield, and increased grain filling periods in the sprayed treatments over the unsprayed once. Grain yield of 342-398 kg/ha in *belg* and of 353-507 kg/ha in *meher* was saved due to the control of rust and net blotch. Losses incurred during *belg* 1997 were attributed to net blotch, as leaf rust didn't appear in this season. However, in the same year of *meher* season net blotch pressure coupled with rust incidence brought the highest grain yield, straw yield, and thousand kernel losses (Table 2). As clearly indicated in Tables 1 and 2 yields were more affected when combined net blotch and leaf rust severity was high or when the severity of any of the individual disease was high. However, explanation of their interaction is beyond the present study and it is suggested that further research be done to analyze the interaction further.

Negative association was observed between disease severity and agronomic traits (grain yield, straw yield and thousand kernel weight). Significant difference between sprayed and unsprayed treatment for most of agronomic parameters proves that losses observed in this experiment are attributed by net blotch and leaf rust, this also shows importance of these diseases in Bale highlands. Previously, yield losses of 6.9-40.2% (Getaneh, 1998) and 25-34% (Eshetu, 1985) due to leaf rust and net blotch, respectively, were determined. Losses of 11-21% (Yitbarek, et. al., 1996) in thousand-grain weight due to net blotch and scald and 6-27% (Getaneh, 1998) in thousand-grain weight due to leaf rust have been also reported. Yield losses due to combined effect of net blotch and leaf rust detected herein were lower than sum of losses previously reported separately. These losses previously identified under high input environments (on station and state farms) were reportedly high. This might be due to high disease intensity, heavier pathogens build up, susceptible variety used and good crop stands than the environments under farmers' circumstances (i.e., used in current study). Thus, result of this study is actual loss that a farmer is experiencing under both seasons.

The losses incurred due to net blotch and leaf rust were also high in monitory terms. With an estimated average producers' price of 95 birr/100kg grain for Bale zone (CSA 1998), 408.5 and 351.5 birr/ha was saved on the average by protecting Arusso form leaf rust and net blotch during *meher* and *belg* season, respectively. Correspondingly, a total of birr 18 942 145 and birr 13 912 370 will be saved from 46 370 ha and 39 580 ha (CSA 1998a & CSA, 1998b) of areas almost planted with Arusso in *meher* and *belg* seasons in Bale highlands.

Moreover, on the average, 757.5 and 389.6 kg/ha available straw from Arusso has been saved in *meher* and *belg* season by protecting net blotch and leaf rust, respectively. Therefore, its logical to generalize that out of the total cultivated area, an average annual available straw yield of 35 125 tons in *meher* and 15 420 tons in *belg* could be saved by protecting the crop from leaf rust and net blotch. According to Girma et al (1996), with the inclusion rate of 50% in the diet, this amount of straw will support the fattening of 102 333 heads of cattle in *meher* and 44 924 cattle in *belg*, each weighing 250 kg.

Fungicide application provided a MRR 29.8 and 50.9% in *belg* and *meher*, respectively. The MRR between 50 and 100% is acceptable for recommendation of a given technology (CIMMYT 1988). However, for the new technology where farmers require learning some skills, a 100% MRR is reasonable (CIMMYT 1988) for recommendation. Thus, with present yield potential of Arusso and current price of 150.68 birr/l spraying using Propiconazole (three times spraying) is not recommended for use. Nevertheless, the economics of 1 - 2 spray at 0.5l/ha need to be further investigated.

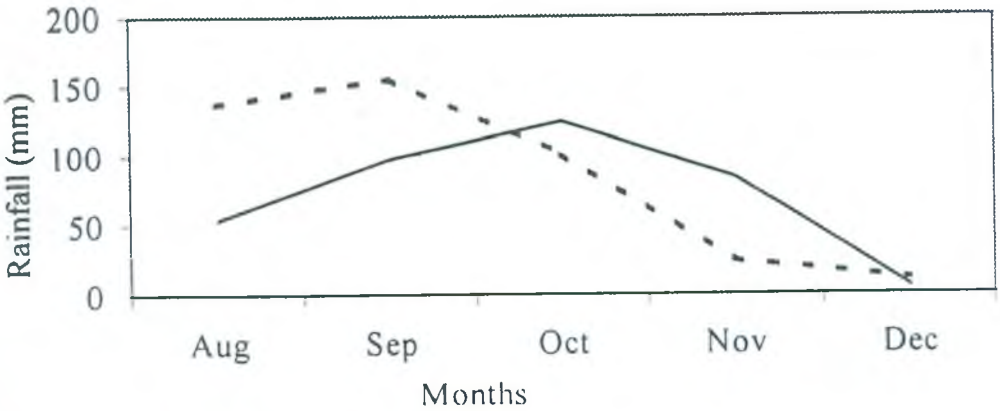

Fig.1 Rainfall of meher season of experimental period (1996-97), Sinana

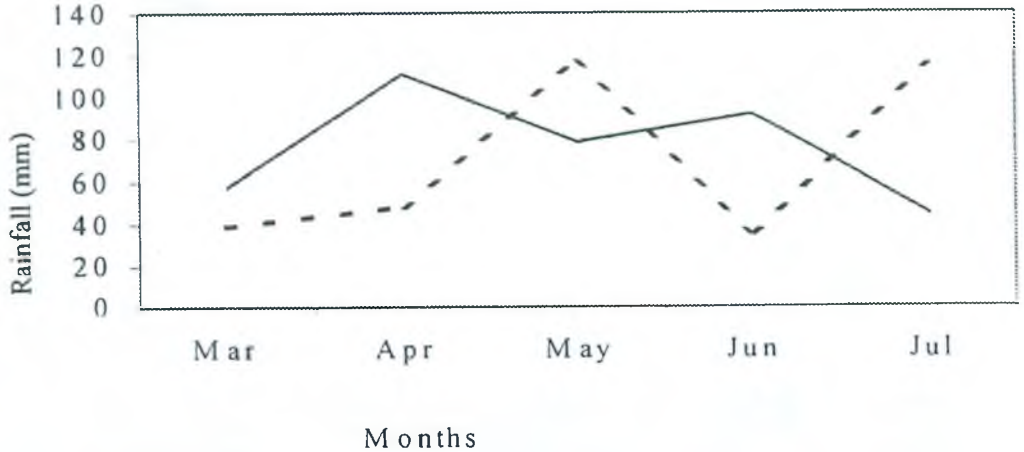

Fig.2 Rainfall of meher season of experimental period (1997-98), Sinana

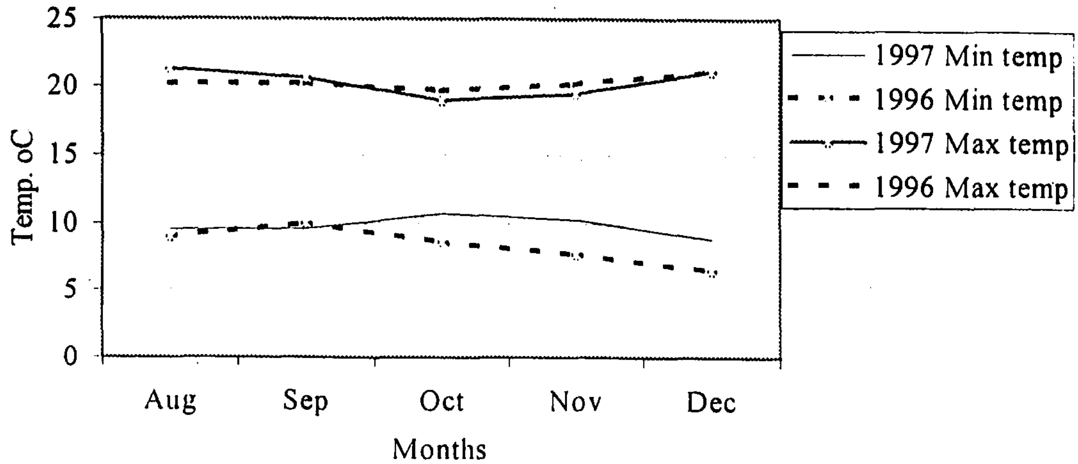

Fig. 3. Temperature during meher season of the experimental period (1996-97)

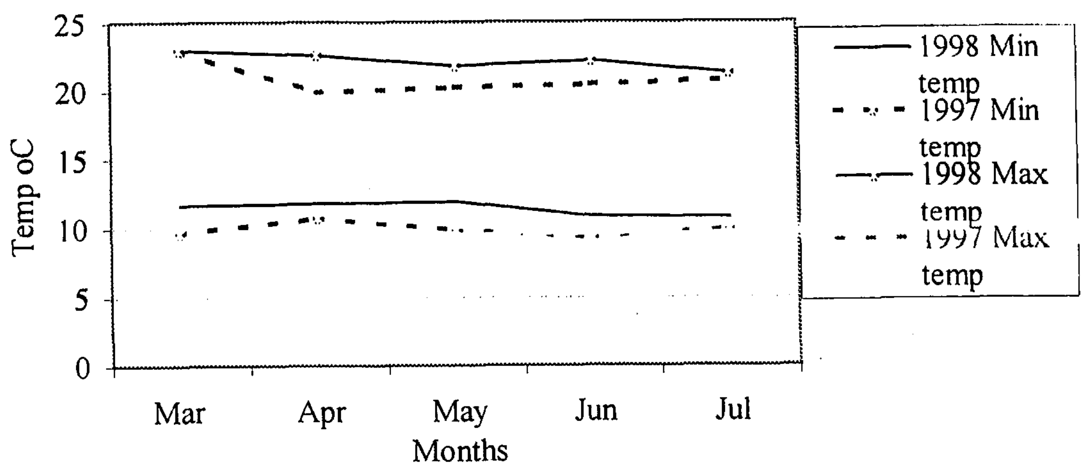

Fig.4. Temperature during meher season of the experimental period (1997-98)

Table 1. Effects of net blotch and leaf rust on barley in *belg*[1] season of bimodal rainfall areas of Bale highlands, 1997-1998

	Treatment	@Netblotch	@ Leaf rust	Plant height (cm)	TKW (g)	Biomass yield (kg/ha)	Grain yield (Kg/ha)	Total straw yield (Kg/ha)
1997	Treated	09B (6.9)	0 (0)	78.2A	-	4350.0A	1361.7A	2988.3 A
	Untreated	1.6A (38.8)	0 (0)	73.8A	-	3625.0B	1019.2B	2605.2 B
	Loss %			5.6		16.7	25.11	12.8
	CV %	16.06		5.86		10.58	16.94	12.5
	SE (+)	0.0688		1.485		139.3553	67.2219	116.846
1998	Treated	0.9B (6.9)	0.8B (5)	82.8A	40.04	3579.9A	1215.9A	2363.9A
	Untreated	1.3A (18.9)	1.1A (11.6)	73.7B	35.55	2451.4B	817.7B	1633.7B
	Loss %			10.9	11.22	31.5	32.75	30.9
	CV %	17.42	11.25	6.21	4.80	14.88	17.72	15.96
	SE (+)	0.0635	0.0353	1.6199	0.6052	149.527	60.0613	106.354
Seasonal loss %				8.2	11.22	24.2	28.93	21.8

Values in each column followed by the same letters are not significantly different at 5%level of LSD test
Figures in parenthesis are disease severity in %
@ Log transformed values of disease severity on which the analysis was based
Belg season means "genna" season in bimodal rainfall areas of Bale
\- *Data was not taken*

Table 2. Effects of net blotch and leaf rust on barley in *meher*[1] season of bimodal rainfall areas of Bale highlands, 1996-1997

1996	Treatment	@Net blotch	@Leaf rust	Plant height (cm)	TKW (g)	Biomass yield kg/ha	Grain yield Kg/ha	Total straw yield (Kg/ha)
	Treated	0.5B (2)	0.2B (0.6)	80.5	41.41	4659.0A	1736.3A	2922.71A
	Untreated	0.7A (4)	0.8A (5)	78.2	41.20	3746.5B	1383.3B	2363.2B
	Loss %			2.9	2.42	19.6	20.33	19.1
	CV %	29.45	61.72	8.43	2.59	10.67	15.4	14.18
	SE (+)	0.0590	0.1034	2.2316	0.3568	149.5177	79.8191	124.8874
1997	Treated	1.0B (9)	0.3B (1)	96.0A	37.51A	5482.6A	1433.0A	4049.6A
	Untreated	1.4A (24)	0.6A (3)	91.2B	32.31B	3369.8B	925.2B	2444.5B
	Loss %			5.0	14.01	38.7	35.43	39.6
	CV %	20.2	59.1	4.4	8.03	28.60	20.71	32.4
	SE (+)	0.0793	0.0849	1.3853	0.9348	421.9424	81.4154	350.1384
Seasonal Loss %				3.9	8.21	29.2	27.88	29.4

Values in each column followed by the same letters are not significantly different at 5%level of LSD test.
Figures in parenthesis are disease severity in %
@ Log transformed values of disease severity on which the analysis was based
[1] *meher season means "bona" season in bimodal rainfall areas of Bale*

Table 3. Economic analysis of fungicide application in barley for *Belg* and *Meher* seasons, in Bale.

Parameters	*Belg* season		*Meher* season	
	Sprayed	Unsprayed	Sprayed	Unsprayed
Average Grain yield (kg/ha)	1288.80	918.45	1584.65	1154.25
Gross net benefit at 0.95EB/kg (EB*/ha)	1224.36	872.53	1505.42	1096.54
Cost of Propiconazole at 150.68EB/lt applied 3 times at a rate of 0.5l/ha (EB/ha)	226.02	0.00	226.02	0.00
Cost of chemical application (EB/ha)	45.00	0.00	45.00	0.00
Total costs that vary (EB/ha)	271.02	0.00	271.02	0.00
Net benefit EB/ha)	953.34	872.53	1234.40	1096.54
MRR (%)	29.8	-	50.9	-

* = *Birr*

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