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Effect of crop residue and fungicide application on malt barley productivity and scald (*Rhynchosporium Secalis*) disease development

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ABSTRACT

Aim: The aim of this study was to determine the impact of barley stubble management and fungicide spray on disease development and barley yield using malt barley Ibon variety.

Materials and Methods: RCBD design was used by involving one barley variety and scald inoculated stubble and fungicide spray plots. Effective fungicide for scald management tilt (Propiconazole250 EC) was used. Treatments combinations were fungicide spray plots, plots inoculated with infected debris (Two months before planting), plots inoculated with infected debris and fungicide sprayed once and control plots.

Results: Inoculated treatments with scald infected stubble showed the highest AUDPC (1295) value followed by control (1135) treatments. The lowest disease severity was recorded from treatments which was receivedtilt fungicide spray. The highest grain yield (4.69 t/ha) was also received from fungicide sprayed treatments. A yield reduction of up to 43% was recorded from unprotected plots compared to the treated plots. Fungicide application reduced scald disease severity, increased yield and kernel weight. However, the magnitude of the impact of fungicide on one or more of these parameters was lower compared with planting barley on infected residue. The highest (2026.09%) marginal rate of return was obtained from fungicide spray plot.

Conclusion: It was concluded that proper timing of fungicide application is crucial if optimal control level is to be achieved. Fungicide applications at the flag leaf stage to directly protect leaves in the upper barley canopy are crucial to ensuring improved malting barley grain yield and kernel weights. Fungicide spraying barley fields and crop rotation could be an effective measure to reduce scald disease severity even on susceptible varieties.

Keywords: AUDPC; Disease Severity; Fungicide; *Rhynchosporium secalis*; Yield.

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Introduction

Barley (*Hordeumvulgare* L.) is one of the cereal crops, domesticated about 10,000 years ago in the Fertile Crescent (Lev-Yadun*et al,* 2000). Barley (*Hordeumvulgare* L.) is the most staple food and subsistence crop in the country. Throughout the history, barley has undergone continuous manipulation in an effort to optimize its use for human consumption and animal feed. Worldwide, it is mainly produced for feeding and malting. The crop is an important commodity and has a long history of cultivation and diverse agro-ecological and cultural practices in Ethiopia (Eticha *et al.,* 2010). Ethiopia is second largest barley producer in Africa (FAO, 2014). It is mainly grown by subsistence farmers in a wide range of environments with an altitude range of 1500 to 3500 m.a.s.l. in the country (Birhanu *et al*, 2005). The crop is predominantly categorized as food and industrial crops used as a raw material for global malting and brewing industries including Ethiopia (Biruk and Demelash. *et al.* 2016). Because of urbanization, population growth, and increasing of beer industry in Ethiopia, malt barley production is increased (Berhane *et al*. 1996).

The share of malt barleyproduction is quite lower (about 15%) thanfood barley in Ethiopia despite the country's having favorable environment and potential market opportunity (Lakew and Fekadu, 2015). The international and national demand of malt barley is directly associated with the expansion of the brewery industries. In Ethiopia, malt barley is the major

(90%) raw material for beer production (MoARD, 2010); hence the country faced a shortage of malt barley to meet the demand of the local breweries (Mohammed and Getachew, 2003). To fulfill the increasing malt barley demand, and to ensure higher cash return to the farmers, expansion of the malt barley production is very important. However, there exists a paradox whereby there are plenty of opportunities, but a scarcity of malt barley due to very low production in the country. The local malt barley production covers about 35% malt demands; as a result the breweries are forced to import malt from abroad (Mollaet *al.,* 2018).

The mean national barley grain yield, 2.5 t ha^{-1} (CSA, 2021), is quite low compared to the world average (2.95 t ha^{-1}), and the top producing countries in the world (Germany, 5.9 t ha^{-1}) (FAOSTAT, 2018). However, the yield potential of some of the recently released improved malting barley varieties can be more than 6 t ha^{-1} (ICARDA, 2016).Its production is mostly affected by a number of biotic factors such as disease (Stewart and Dagnatchew, 1967; Eshetu, 1985) and insect pests recorded (Adunga and Kemal, 1986) on barley in Ethiopia. Scald is among a serious foliar disease occurs worldwide wherever barley is grown (Shipton, 1974). It is also considered among the most important biotic stresses in barley causing high yield loss in Ethiopia. This pathogen can cause dramatic yield reductions, up to 40%, along with reductions in grain quality (Jenkins &Jemmett, 1967) and losses of nearly 100% can occur on susceptible barley cultivars (Yahyaoui, 2004). Yield losses occur mainly through reduced 1000 grain weights, although other above ground parts may be reduced as well (James *et al.,* 1968).

It is a serious disease in cool, semi-humid areas especially with dense crop canopies where leaves remain wet for long periods (Zaffarano*et al.* 2008).The *R.secalis*, can infect rye and wild grass species as well as cultivated barley (Zaffarano*et al.,* 2006). Control of *Rhynchosporium* by use of cultivar resistance, cultural practices or fungicides has not proved to be sustainable (Xi *et al.,* 2000a). The *R. secalis* population can change rapidly so that new barley resistance genes and fungicides become ineffective after several seasons of Wide spread commercial use (Newton *et al.,* 2001; Oxley*et al.,* 2003).

*R. secalis*is a polycyclic barley disease, normally involving several pathogen generations during a growing season, and secondary disease spread frominfected leaves by splash-dispersed *R. secalis* conidia (Fitt *et al.* 1989). During each generationthe conidia germinate and infect new host tissues. *R. secalis* grows symptomless under the cuticle, especially where walls of adjacent cells are joined (Jones and Ayres, 1974), before producing new conidia (Davis *et al.*, 1994) and finally, visual symptoms (Shipton *et al.*, 1974). Given this long symptomless phase and the fact that the life-cycle can be completed by sporulation before appearance of visual symptoms, there is a good case that *R. secalis* should be classified as a hemibiotrophrather than a necrotroph (Oliver and Ipcho, 2004).

Scald is a stubble and seed-borne disease which is favored by high rainfall environments. This disease is most damaging in the high rainfall. Based on the complexity of the pathogen, control of the disease requires an integrated and multifaceted approach, including application of fungicides, manipulation of sowing date, cultural disease management, and the use of resistant cultivars (McLean and Hollaway, 2018); though using resistant varieties provide the easiest and most effective option to manage the disease. Continuous cropping with the same susceptible host plant will result in the inoculum build-up of the pathogen population. Rotating any crop other than barley between barley crops in a field will significantly reduce the potential for barley scald disease. Continuous barley cultivation leads to the accumulation of crop debris in the field and, with it, to a build-up of inoculum (Elen, 2002).

Barley scald is the greatest destructive pathogen of barley worldwide, causing yield loss of up to 40% and reduced grain quality (Zhan *et al.* 2007). The pathogen is a polycyclic, normally involving several pathogen generations during the growing season, and secondary disease spread by splash-dispersed conidia (Zaffarano *et al*. 2006 and Zaffarano *et al*. 2008). The pathogen causes lesions ranging from spots to short yellow streaks on leaves, and the lesions can expand into longer longitudinal and transverse necrotic streaks (Mathre and Mathre, 1997). In Ethiopia, many diseases of barley were reported; however, leaf scald and net blotch are the most widely distributed diseases of the crop (Hunde *et al.* 2011). The disease can cause yield losses ranging from 30% to 40% and decrease grain quality (Zhan *et al.* 2007). In the high lands where precipitation is high and temperature is low during the cropping period, which is a scald favorable season on a susceptible cultivar, yield loss reaching 67% has been recorded in Ethiopia (Semeane*et al.* 1996). In the long period of evolution, crop plants have naturally developed broad defense mechanisms mainly through avoidance, tolerance, and resistance to protect themselves from their pests.

The development of sustainable strategies for the management of *Rhynchosporium* depends on an improved understanding of the biology of *R. secalis* and its interactions with the barley host and fungicides. Common control measures include crop rotation, stubble destruction, use of chemical fungicides and resistant barley varieties. Some resistant barley varieties have been found to be vulnerable with time. Rotation of farm lands is one means of managing disease with shrinking land-size coupled with growing demand of malt barley, rotation will become counterproductive in times ahead. Synthetic fungicides have been implicated with negative environmental impacts due to their toxic, non-biodegradable and indiscriminate nature. To mitigate this, modern day scientist's main duty is to seek ways of managing plant diseases with minimal impact to the environment. The path to find alternatives has been advanced in several fronts; crop rotation is one such alternative. The objective of this study was to determine the effects of crop residue and fungicide application on barley leaf scald disease severity, production and productivity.

Materials and Methods

Description of the study areas

The study was conducted at Holetta Agricultural Research Center, Ethiopia. The average annual rainfall of the study area is 1100 mm and the maximum and minimum annual mean temperatures were 22.2°C and 6.13°C, respectively. The site receives higher rainfalls, is suitable for barely production and its conducive for *R. secalis* disease development.

Treatments and experimental design:

The experiment was conducted in the main cropping season of 2020/21. A variety susceptible to leaf scald disease, IBON was used to execute the experiment. Effective fungicide for scald management tilt (Propiconazole250 EC) was used. Treatments combinations were fungicide spray plots, plots inoculated with infected debris (Two months before planting), plots inoculated with infected debris and fungicide sprayed once and control plots (received none). Fungicide was applied using manual knapsack sprayer. Tilt was applied at a rate of 0.5 lt/ha, at the disease onsets. During fungicide sprays, plastic sheet was used to separate the plots being sprayed from the adjacent plots and prevent inter-plot interference due to spray drift. A control plot was free of infected stubble inoculation and fungicide spray (farmers practice). Treatments were arranged in a plot size of 2m by 1.2 min randomized complete block design (RCBD) with three replications. Natural infection was used as a source of inoculums (Jebbouj and El Yousfi, 2010). Agronomic practices such as weeding; fertilizer application and harvesting were performed uniformly based on recommendations of local practices.

Disease severity:

Leaf scald severity was assessed five times based on the disease progression from the middle of four rows from 10 randomly selected and tagged barley plants at 7 days intervals starting from the onset of symptoms until the crop is physiologically matured (Arabi *et al.* 2004). A severity assessment was done on a scale of 00–99 severity scale (Singh *et al.* 2014). The disease severity scores were converted to percentage severity index (PSI) (Silvar *et al.* 2010).

$$PSI = \frac{Snr}{Npr \ x \ MSc} x100$$

Where Snr is the sum of numerical ratings; Npr is the number of plants rated; Msc is the maximum score on the scale.

Area under disease progress curve:

The rate of disease increase in the field and the cumulative amount of the disease over time expressed as area under disease progress curve (AUDPC) provides use full overall measures of disease progression. AUDPC was calculated for all treatments according to the following function or equation models developed by Sharma and Duveiller (2007).

$$AUDPC = \sum_{i=1}^{n-1} 0.5(\mathrm{xi} + 1 + \mathrm{xi})(ti + i - ti)$$

Where N is the number of observations, ti is the days after planting for the ith disease assessment, and xi is the disease severity in percent.

Yield and yield components
Data on the yield and yield components were recorded from four central rows for each treatment. The weight of thousand kernels and hectoliter weight were sampled at random from the total grains harvested were measured. Grain yield (GY) in gram per plot (g/plot) at 12.5% moisture content was recorded and converted to kg/ha.

Relative Yield Loss (%):
Percent relative grain yield loss was calculated as follows:

$$\text{RYL (\%)} = \frac{(Yp - Yt)}{Yp} x100$$

Where, RYL= relative yield loss in percent, Yp = yield from the maximum protected plots (sprayed three times) and Yt = yield from other plots.

Cost - Benefit Analysis
Price of barley grains was assessed from local market and taking into account the total price on hectare basis andfungicides (Tilt) required and total price incurred to spray were calculated. Labor to spray chemicals and to manage the experiment was computed. Payment for labor was Birr 50 days-1 at both locations. Cost of spraying and spray equipment to spray was also calculated. Based on the data obtained from field, the cost-benefit analysis was performed using partial budget analysis. The difference between treatments, the option economic data was subject to analysis using the partial budget analysis method (CIMMYT, 1988). Marginal rate of return was calculated using the formula.

$$\text{MRR(\%)} = \frac{\Delta \text{NI}}{\Delta \text{IC}} X100$$

Where, MRR- is marginal rate of returns,
ΔNI – change in net income compared with control, and
ΔIC – change in input cost compared with control.

Statistical analysis
Data on disease parameters such as disease severity, AUDPC, yield, and yield component were analyzed by using the general linear model (GLM) procedure of SAS 9.2 software. Significant difference among treatment means was assessed using least significant difference (LSD) at ($p< 0.05$) different.

Results and Discussion

Disease severity
The Final disease severity of barley scald was significantly ($p< 0.05$) affected by treatments. The disease severity was increased as the crop approached maturity in all treatments.Among the treatments, inoculated plots with infected straw were showed the highest final disease severity 66.67% followed by control treatments (55.00%) which was free of fungicide spray and inoculation of infected straw. This finding is in line with Bekele *et al.* (1995), which states *Rhynchosporiumsecalis* survives as mycelia and conidia on infected host residues, controlling scald by cultural practices such as rotating barley with non-susceptible crops are options that delay disease onset.The result is also supported by; crop rotation is useful in reducing inoculum of R. commune which can be spread from crop debris (Oxley and Burnett, 2009). Also Elen (2002), emphasize the importance of crop rotation in controlling the occurrence of the disease on barley. The lowest final disease severity (26.67%) was recorded from treatments sprayed with fungicide and the second lowest (30.00%) disease severity was recorded on inoculated treatments with infected straw and supported by fungicide spray however no significant variations were observed between the treatments. This is because of, fungicides applied can greatly decrease disease development and therefore increase yield, when applied at appropriate growth stage of the crop (Young *et al.,* 2006). Scald of barley is more likely to be a problem when infected trash remains from a previous barley crop. Crop rotation could also be useful in reducing inoculum of foliar pathogens which can be spread from crop debris e.g. R. commune (Oxley and Burnett, 2009).

Area under disease progress curve
The AUDPC value was significantly ($p < 0.05$) affected by treatments (Table 1). The effects of treatments on diseases infection rate during evaluation were not equally infected. Significantly highest scald AUDPC value of 1295.00% were recorded from plotsinoculated with infected debris treatments followed by 1135.00% control treatments. While significantly lower 765.0% AUDPC values were recorded from treatments that received fungicide spray. Scald

disease severity had progressively increased on the malt barley variety as they mature under field conditions, also Williams *et al.* (2003), reported that higher percentage severity was recorded when the plant becomes older and the resistance genes in the genotype are only effective at seedling stage of plant growth.

Effect of scald disease on yield and yield components of malt barley

Grain Yield and Yield Loss: Yield and yield components were significantly ($p < 0.05$) affected by treatments (Table 1). The Grain yield losses attributed to scald epidemics range from 5 to 45% (Shipton*et al.*, 1974). The highest and significantly different grain yield of 4.69 t/ha were received from fungicide sprayed treatments. The lowest grain yield of 2.67 t/ha were received from stubble inoculated plots followed by control treatment (3.06t/ha) but does not showed significantly variations. The highest 43.07% of grain yield loss were recorded from stubble inoculated treatments referred to treatments sprayed with fungicides. Also, the highest hector litter weight (65.27 kg/hl) was recorded from plots received fungicide spray. Yield losses are ascribed to reductions in all yield components, particularly kernel weight and kernel number per spike (James *et al.*, 1968). Low kernel weight may lead to a malting barley crop being sold for feed at a lower price (Nutter *et al.*, 1985). By managing the disease using fungicide, such as Tilt, can effectively control scald (Johnston and MacLeod, 1987) and improve production. Multi-component mixtures, while effective in reducing scald severity, (McDonald *et al.*, 1988), are not feasible in malting barley production, where the industry demands a homogeneous product meeting exacting quality standards.

Cost Benefit Analysis

The Partial budget analysis indicated that stubble inoculated and fungicide spray plot requires the highestcost of production (5,700.00 ETB) while the control plots had the lowest cost for production (3100.00 ETB) (Tables 2). On the hand, protected plots from scald disease of barley with fungicide spray gave the highest net benefit (135,300.00 ETB) followed by stubble inoculated and fungicide spray plots. Plots inoculated with scald infected stubble showed the lowest net profit than other treatments.

Table 1: Effect of stubble and fungicides application on Barley scald disease, yield and yield components at Holetta during 2019/20 main cropping season

Treatments	Final disease severity (%)	AUDPC (%)	Yield t/ha	RYL (%)	TSW(g)	HLW (kg/hl)
Stable Inoculated	66.67a	1295.00a	2.67c	43.07	46.80b	59.03c
Fungicide sprayed	26.67c	765.00d	4.69a	0	49.20ab	65.27a
Stable inoculated and fungicide spray	30.00c	932.50c	3.83b	18.34	52.00a	61.07b
Control	55.00b	1135.00b	3.06c	34.76	48.13b	58.90c
Mean	44.58	1031.88	3.56		49.03	61.07
LSD(0.05)	8.33	108.64	0.44		3.74	1.53
CV	9.35	5.27	6.20		3.82	1.25

Where, AUDPC; Area under disease progress curve, TSW; Thousand seed weight, HLW; Hecto litter weight

Means in a column followed by the same letters are not significantly different according to LSD at 5% probability level

Table 2. Partial budget analysis for the management of barely scald disease during the main cropping season of 2019/20.

Treatments	Yield (t /ha)	Sale (ETB kg^{-1})	Sale revenue (ETB Birr)	Total cost (birr/ha)	Marginal cost (birr/ha)	Net profit (birr/ha)	Marginal benefit	Marginal rate of return (%)
Stable Inoculated	2.67	30.00	80,100	3400.00	300.00	76,700	-12,000	-4,000.00
Fungicide sprayed	4.69	30.00	140,700	5400.00	2300.00	135,300	46,600	2026.09
Stable inoculated & fungicide sprayed	3.83	30.00	114,900	5700.00	2600.00	109,200	20,500	788.46
Control	3.06	30.00	91,800	3100.00	0.00	88,700	0.00	0

It indicated that by applying only crop rotation growers can produced reasonable higher grain yield. Also, plots sprayed with fungicide gave the higher rate of return (2026.09%) than any treatment. These finding were in agreement with the finding of Conry and Dunne (2001) that recommended fungicides for diseases management increases yield of the grains. Therefore, higher grain yield can be obtained by rotating with non-host crops and applying effective fungicides for diseases management.

Conclusions

It was concluded that proper timing of fungicide application is crucial if optimal control level is to be achieved. Fungicide applications at the flag leaf stage to directly protect leaves in the upper barley canopy are crucial to ensuring improved malting barley grain yield and kernel weights. Also, these findings revealed that fungicide spraying barley fields and crop rotation could be an effective measure to reduce scald disease severity even on susceptible varieties. Crop rotations to non-host crops have the ability to provide succeeding crops, reduce disease incidence, and improve weed control strategies. Therefore, giving more attention to develop different scald management strategies including variety-fungicide combinations and applying crop rotation is important.

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