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Research Article

Determination of Fungicide Spray Schedules for the Management of Barely Scald Disease

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ABSTRACT

Scald is an economically important foliar disease in the major barley-growing areas of Ethiopia. The current research was conducted to determine the impact of barley varieties and tilt fungicide spray schedule on disease development and barley yield. The effect of barley varieties and fungicides spray schedule on Scald development and barley yield was evaluated at Holetta in a factorial field experiment involving three barley varieties and four fungicide spray schedule. Variety Savini had the highest AUDPC (4762) value followed by Ibon (1888) and HB-42 (1402) varieties. Scald severity were significantly reduced by the application fungicide across varieties. Barley grain yield were the lowest from unsprayed plots regardless of variety. Tilt fungicide spray produced the highest yield (3.77t/ha). The highest (7131%) and lowest (0%) marginal rate of return were obtained from Ibon variety 14th day interval fungicide spray and from all unsprayed fields, respectively. The present findings confirmed the importance of Scald in Ethiopia and the role fungicides spray schedule play in managing the disease on partially resistant varieties. Therefore in future, giving more attention to develop different Scald management strategies including breeding and screening for Scald resistance varieties and variety-fungicide combinations is important.

Keywords: AUDPC; Barley; *Rhynchosporium secalis*; Scald; Tilt; Yield; Hecto litter weight; Thousand kernel weight; Disease severity; Cost benefit analysis

INTRODUCTION

Barley (*Hordeum vulgare* L. ssp. vulgare, 2n=14) is a member of family Poaceae. It is considered fourth largest cereal crop in the world after maize, rice and wheat with a share of 7% of global cereal production. It is also known as poor man's crop because of its low input requirement and better adaptability to drought, salinity, alkalinity and marginal lands [1]. This cereal is adapted to dry areas characterized by erratic rain and poor soil fertility which is often described as low-input barley (LIB) production systems [2]. It is categorized as hulled and hull less barley on the basis of grain type. In hulled barley the lemma and palea are fused to the pericarp whereas in hull less the chaff is easily separated from the grain. Hull less barley is mainly preferred as food for human consumption [3].

Because of its multifarious utilities, nutritive value and ever-increasing industrial demand, a substantial yield gains will be needed over the next several decades. It is one of the world's most important crops providing food and related products for millions of people. Diseases continue to pose a serious threat to barley production, despite the use of fungicides and resistant varieties. But, a number of biotic and abiotic stresses pose a challenge to increase the production of barley. Like the other cereals, barley also encounters different plant pathogens and succumbs to various diseases which result in significant yield reduction and poor grain quality. Diseases occur when a susceptible host is exposed to a virulent pathogen under favorable environmental conditions and they may affect barley yields from 1 to 100% depending on the susceptibility of varieties, virulence level of pathogens, growth stage of crop at the time of infection, favorable weather conditions and time of availability of inoculum and nutrients [4]. Disease control in barley requires proper management and sound agronomic practices no matter which tillage system is used. Weather conditions and crop rotations are usually much more influential than the tillage system in determining disease intensity in barley [5]. Despite barley's long history of cultivation in Ethiopia with diverse farmers' varieties, traditional practices, and its valuable uses [6], the production and productivity of the crop have been low (<2 t/ha) [7]. This yield level is lower than worldwide and national yield potential [6,8] obtained under well managed plots in the country [9]. The low productivity of the crop is associated with multidimensional abiotic and biotic factors. Among the yield limiting biotic factors, diseases remain a major biotic constraint on barley production in Ethiopia [10]. In Ethiopia, among nearly 40 diseases of barley reported, leaf scald

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caused by *Rhynchosporium secalis* (Oud.) J.J. Davis and net blotch caused by *Pyrenophora teres* Drechs are the main and most widely distributed diseases of the crop [11,12]. Both diseases are observed in the highlands where precipitation is high and temperature is low during the cropping period. Hence, during a scald-favorable season and on a susceptible cultivar, a yield loss of up to 67% has been demonstrated. Overall barely scald disease has remained an important constraint to barely production in Ethiopia. However, effective and sustainable managing of the disease is yet to be achieved under Ethiopian condition. In Ethiopia, barely is grown in different agro-ecological zones. The areas vary in-terms of weather conditions, barely varieties grown and crop management practices. The crop contributed a great deal to the country as source of food and income but it is continuously ravaged by diseases and other biotic constraints. Scald is one of the major diseases of barely around the world and across wheat growing regions of Ethiopia [13-15]. The disease occurs almost in all barely growing places but its intensity varies from place to place due to variability in weather conditions, differential responses of barely varieties to the disease and as a result of variations in crop management practices [16]. Yield loss assessment studies have been carried out in fewer areas and they are largely based on data from field surveys. As a result there is a need to develop disease management option and recommend in areas, where the disease is prevalent and economically important. Thus, this study was designed with the objectives: To evaluate the effect of barely varieties and Tilt fungicide schedules on scald and barely yield and to contribute towards improved barely production in the central highlands of Ethiopia through effective and sustainable management of scald disease.

MATERIALS AND METHODS

Description of the study areas

The study was conducted at Holetta Agricultural Research Center, Ethiopia. Holetta Agricultural Research Center is located at 29 Km West of Addis Ababa at 09°04'N latitude and 38°38'E longitude and at elevation of 2390 m.a.s.l. The average annual rainfall of the area is 1100 mm and the maximum and minimum annual mean temperatures are 22.2°C and 6.13°C, respectively. The site is suitable for barely production, and Scald disease pressure is generally high during the rainy season.

Treatments and experimental design

The experiment was conducted in the main cropping season of 2020/21 (June to January). The experiment consisted of factorial treatment combination of three barely cultivars with differential reaction to Scald (Table 1), and three spray schedules of systemic (Tilt) fungicide. All the three varieties were planted at a seed rate of 125 kg ha-1 and fertilizer rates of 57 and 57.5 kg ha-1 **N** and **P_2O_5**, respectively. Treatments were arranged in randomized complete block design (RCBD) with three replications.

Fungicide was applied using manual knapsack sprayer. Tilt was applied at a rate of 0.5 lt/ha with two up to four sprays frequencies, respectively, beginning from the time of disease onset. 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. Unsprayed plots were included as negative checks. Twenty plants per plot were tagged for evaluation of disease parameters. Agronomic data were collected from the central four rows. All recommended agronomic practices to the area were adopted.

Data collected

The field experiment was conducted under natural infections, and disease severity was assessed on the central four rows every seven days starting from the first occurrence of disease symptoms up to maturity of the crop.

The severity of scald was recorded using percentage (0-100%). Area under Disease Progress Curve (AUDPC) values were calculated for each plot using the equations developed by Sharma and Duveiller [17] as follows.

$$AUDPC = \sum_{i=1}^{Ni-1} \frac{(Xi+Xi+1)}{2}(ti+1-ti)$$ Where,

Xi= the cumulative disease severity expressed as a proportion at the i^{th} observation,

ti = the time (days after planting) at the i^{th} observation and n= total number of observations.

Since barely leaf scald severity had been expressed in percent and time (t) in days, AUDPC values can be expressed in %- days [18]. Then AUDPC values are used in analysis of variance to compare amount of disease among different treatments.

All agronomic, yield and yield related data were recorded on the middle four rows of each experimental plot. These data along with their details are mentioned below:

- **Thousand Kernel weight (TKW) (g):** One thousand grains selected at random were weighed in grams for each experimental unit.
- **Hectoliter weight (HLW) (Kg/hL):** Grain weight of one-liter volume (random sample) was estimated for each experimental unit by following standard procedure [19] and the result were converted to Kg/hL. The moisture content was adjusted at 12.5%.
- **Grain yield (GY) (tones):** Grain yield in g/plot at 12.5% moisture content were recorded and converted to t/hectare.

Cost benefit analysis

Price of barely grains (30 Birr/kg) was computed based on the current local market, total price of 100 kg (3000 Birr) obtained from a hectare basis, costs that vary like fungicides (Tilt=1,900 Birr/lt) and labor costs (50 Birr/LD) to apply the fungicide were recorded and taken into account. The total amount of these materials (fungicides, seeds, labor and water) used for the experiment were computed and its price converted. Before doing the economic analysis (partial budget), the statistical analysis was done on the collected data to compare the average yield between treated and untreated treatments respectively. The partial budget analysis was calculated using the formula established to calculate marginal rate of return by CIMMYT [20]. The difference between treatments and the economic data were used to do partial budget analysis as follows: Marginal rate of return was calculated using the following formula.

$$MRR = \frac{DNI}{DIC}$$

Where, **MRR** = Marginal Rate of Returns (Cost benefit ratio).

DNI = The difference in net income compared with the control.

DIC = The difference in input cost compared with the control.

Data analysis

Data on Scald severity were subjected to log transformation before analysis. Data analysis was carried out using the general linear model of the SAS computer package version 9.3 [21]. Means for treatments were compared using Duncan's New Multiple Range Test (DNMRT).

RESULTS AND DISCUSSION

Disease severity

Barely scald severity vary significantly among varieties during the first up to seventh assessment date; whereas there is no significance difference among fungicide schedules and management options during first and second assessment date at Holetta (Table 2). From 3rd –5th assessment date, the unsprayed plots showed significantly higher (33.3%-60.3%) disease severity, while other treatments did not vary significantly from each other. At 6th and 7th assessment date there is significance difference among fungicide schedules; the highest disease severity (36.1-41.1%) recorded on 14th date and 21st fungicide spray schedule whereas the lowest disease severity (32.2-32.8%) recorded on 7th date spray interval. Among varieties the highest disease severity (78.1%) recorded on Savini; whereas the lowest value (23.7%) on HB-42. Among management options the highest final disease severity (52.1%) recorded on stubble applied plots whereas; the lowest final disease severity (42.3%) recorded on without stubble applied plots. This showed that the level of disease development is considerably affected by level of fungicide application or improvement of varietal resistance to scald as a result of fungicide spray. The effect of crop resistance level on latent period of Scald pathogens and the rate of disease development [22].

Current results also revealed that spraying barely fields could be an effective measure to reduce Scald levels even on susceptible varieties. In practice, the rate and frequency of fungicide application must depend on the level of risk acceptable to the producer, which in turn depends on the economic return from the crop [23]. Although complete control of Scald development was not achieved and level of control varied across varieties, spraying Tilt fungicide schedules significantly reduced the severity level on all varieties. Inability of fungicide to reduce Scald severity to zero level might be due to the presence of conducive environmental condition for the development of Scald at growing period; especially sufficient rain fall and suitable temperature. The presence of sufficient rain fall not only favors development of Scald but also it might reduce the efficiency of fungicide.

Area under disease progress curve

Barely scald area under disease progress curve (AUDPC) across treatments expressed as AUDPC%-days ranged from 1402 to 4762 among varieties and from 2529 to 3250 among fungicide spray schedules (Table 2). Results of the current work revealed highly significant ($p \leq 0.001$) differences among treatments in terms of AUDPC. AUDPC is a very convenient summary of plant disease epidemics that incorporates initial intensity, the rate parameter, and the duration of the epidemic which determines final disease intensity [24]. AUDPCs were generally higher on unsprayed plots than on sprayed plots. The maximum values (3250%-days) recorded on unsprayed plots whereas the lowest AUDPC value (2305%-days) recorded on 7th day spray schedules (Table 3). Among varieties the highest AUDPC value (4762%-days) recorded on Savini which is susceptible variety for barely leaf scald disease whereas the lowest AUDPC value (1402%-days) recorded on HB-42 which is resistant for barely scald disease (Table 2). Among stubble management options the highest AUDPC value recorded on stubble applied plots whereas the lowest value recorded on without stubble applied plots (Table 4). This agrees with that of studies [25-28], who reported maximum AUDPC values (2275%-days) from unsprayed plots.

Yield and yield components

Grain yield: Grain yield showed a significant ($p \leq 0.05$) difference among treatments (Table 3). Among varieties the highest yield (4.43 t/ha) was recorded on HB-42 variety; whereas the lowest yields (2.1 t/ha) were recorded from Savini variety, respectively. Among fungicide schedules the highest yield (3.77 t/ha) was recorded on 14 days interval fungicide schedule; whereas the lowest yields (3.22 t/ha) were recorded from unsprayed plots. Among management options the highest yield (3.53 t/ha) was recorded from without stubble applied plots; whereas the lowest

Table 1: Barely varieties used in the field experiment.

S.No	Varieties	Year of Release	Adaptation (m.a.s.l.)	Daysto Maturity	Reaction	Yield (t/ha)
1	Ibon	2012	2002-3000	Medium	MS	2.6-5.2
2	HB-42	1984	2004-3000	Late mature	MR	3.3-5.2
3	Sabini	2011	2002-3000	Medium	HS	3.5-4.5

MR= Moderately Resistant, MS= Moderately Susceptible, HS= Highly Susceptible

Table 2: Effect of Barely varieties on scald disease severity at Holetta during 2020 main cropping season.

Treatment	Disease Severity (%)								Yield & Yield Components		
Varieties	1st	2nd	3rd	4th	5th	6th	7th	AUDPC	HLW	TKW	YLD (t/ha)
Savini (V1)	34.4a	46a	56.1a	50.9a	55.9a	74.8a	78.1a	4762.2a	63.1a	39.6c	2.1c
Ibon (V2)	12.9b	14.1b	17.1b	19.6b	26.8b	33.3b	34.8b	1888b	59.4a	51.1b	3.84b
HB42 (V3)	13.2b	12.9b	13.5c	13.8c	19.6c	21.8c	23.7c	1402.3c	59.4a	55.6a	4.43a
Mean	20.3	24.3	28.9	28.1	34.1	43.3	45.6	2684	60.7	48.7	3.46
CV	27.2	16.8	15.7	18.2	15.9	16.1	16	13.1	13	7.2	19.5
LSD (5%)	3.74	2.77	3.08	3.47	3.68	4.74	4.93	237.4	5.35	2.37	0.46

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

Table 3: Effect of fungicides on scald disease severity at Holetta during 2020 main cropping season.

Treatment	Disease Severity (%)								Yield & Yield Components		
Schedules	1st	2nd	3rd	4th	5th	6th	7th	AUDPC	HLW	TKW	YLD (t/ha)
Unsprayed	19.1a	22.9a	32.5a	33.3a	41.8a	60.1a	63.8a	3249.8a	60.7a	46.4b	3.22a
7th day Interval	21.5a	25.2a	25.6b	23.8c	28.6b	32.2c	32.8c	2304.6b	59.3a	50.7a	3.66a
14th day Interval	18.9a	24.3a	27.6b	25.7bc	31.5b	39.1b	41.1b	2466.6b	62.2a	50.2a	3.77a
21 day Interval	21.6a	25.5a	27.8b	28.5b	32.3b	36.1bc	39b	2529b	61.7a	48ab	3.22a
Mean	20.3	24.3	28.9	28.1	34.1	43.3	45.6	2684	60.7	48.7	3.46
CV	27.2	16.8	15.7	18.2	15.9	16.1	16	13.1	13	7.2	19.5
LSD (5%)	4.57	3.39	3.78	4.25	4.5	5.8	6	290.76	6.55	2.9	0.56

Table 4: Effect of stubble on scald disease severity at Holetta during 2020 main cropping season.

Treatment	Disease Severity (%)								Yield & Yield Components		
Management	1st	2nd	3rd	4th	5th	6th	7th	AUDPC	HLW	TKW	YLD (t/ha)
No Stubble	19.9a	24a	27.8b	27.3a	33b	40.5b	42.3b	2572.1b	60.3a	48.8a	3.53a
Stubble	21.07a	25a	31.3a	29.6a	36.3a	48.9a	52.1a	2908.2a	61.3a	48.7a	3.32a
Mean	20.3	24.3	28.9	28.1	34.1	43.3	45.6	2684	60.7	48.7	3.46
CV	27.2	16.8	15.7	18.2	15.9	16.1	16	13.1	13	7.2	19.5
LSD (5%)	3.24	2.4	2.67	3	3.18	4.1	4.3	205.6	4.6	2.05	0.4

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

yields (3.32 t/ha) were recorded from with stubble applied plots. This finding is in agreement with [26-28], who recorded the highest yield from 10 days interval sprayed plots and the lowest yield from 30 days interval sprayed plots and unsprayed plot. Grain yield from unsprayed plots, which averaged from 3.22 t ha^{-1} at Holetta were significantly lower than those from sprayed plots 3.77 t ha^{-1} [25-28]. Also reported lower qualitative and quantitative grain yield from untreated plots in comparison with treated one.

Thousand kernel weight: Analysis of variance (ANOVA) revealed that fungicide applications showed significant difference in thousand kernels weight. Under Holetta conditions, thousand kernels weight was significantly highest on HB-42 variety (55.6 gm) and Ibon (51. gm); the lowest recorded from Savini variety (39.6 gm) which was the most susceptible for barely leaf scald disease (Table 3). Among fungicide schedule the highest TKW (50.7 & 50.2g m) recorded on 7th and 14th day's schedule, whereas; the lowest TKW (46.4 gm) recorded from unsprayed plots. In most cases different fungicide regimes did not differ significantly in terms of thousand kernels weight regardless of the locations.

Hectoliter weight: The highest hectoliter weight (63.1 kg/hl) was recorded on variety Savini sprayed with Tilt; whereas, the lowest hectoliter weight (59.4 kg/hl) was recorded on Ibon and HB-42 varieties at Holetta condition (Table 3). Among fungicide spray schedules, the highest hectoliter weight (62.2 and 61.7 kg/hl) was recorded on 14th day and 21st day fungicides schedule, respectively; whereas, the lowest hectoliter weight (59.3 kg/hl) was recorded on unsprayed plots. Among stubble management options; the highest the highest hectoliter weight (61.3 kg/hl) was recorded on without stubble applied plots; whereas, the lowest hectoliter weight (60.3 kg/hl) was recorded on stubble applied plots. There was no significance difference between different fungicide schedules, varieties and management options in hectoliter weight.

Cost benefit analysis

Partial budget analysis indicated that spraying fungicide within 7 days interval had the highest total cost (7025ETB) while the unsprayed plots had the lowest cost (3225ETB) (Tables 4). On the other hand, partial budget analysis indicated that fungicide spray schedules used on the three varieties gave high gross field benefit and marginal rate of return. At Holetta on variety Ibon, the partial cost benefit analysis showed that the maximum marginal rate of return 7131.60 Ethiopian Birr per hectare was obtained from plots treated with fungicide on 14th day spray schedules. This was followed by plots treated with spray interval with 7 days with a marginal rate of return of 5173.70 Ethiopian Birr per hectare. Therefore, reasonable benefits were obtained in the fungicide sprayed plots. Slafer GA [29] indicated that when assessing a crop for risk, it is also necessary to asses it for the potential to cover the cost of application which depends on the potential yield. Fungicides are used because they provide effective and reliable disease control, deliver production in the form of crop yield and quality at an economic price and can be used safely [30]. However, farmers would refrain from using fungicides unless proven effective and profitable.

CONCLUSION

Barley (*Hordeum vulgare* L) is one of the most important cereal crops in Ethiopia. It is widely grown in most of the regions in the country, including the Central highlands. However, its production is affected by abiotic and biotic factors. Among the biotic factors, *Rhynchosporium secalis* (Scald) is one of the important problems of barley production in the country. The major objective of the study was to contribute towards improved barley production in the central highlands of Ethiopia through effective and sustainable management of *Rhynchosporium secalis*. A field experiment was conducted at Holetta in 2020 main cropping season to quantify the severity of *Rhynchosporium secalis* and to determine the effect of this disease on yield and yield components of barley varieties. Four different spray schedules of propiconazole (Tilt 250 EC) were combined with three barley varieties (Ibon, HB-42 and Savini) to create different levels of Scald at Holetta field condition. Scald resulted in significant yield loss of barley varieties, when left unchecked. However, fungicide treatments significantly reduced Scald severity relative to untreated plots. Final Scald severity was

23.7, 34.8 and 78.1% at Holetta; on HB-42 (moderately resistant), Ibon (moderately susceptible) and Savini (Highly susceptible), respectively. Current results also revealed that spraying barley fields could be an effective measure to reduce Scald levels even on susceptible varieties. The highest yield (4.43 t/ha) was recorded on HB-42 variety sprayed with tilt fungicide at Holetta.

The efficacy of tilt fungicides to control scald has been verified by this study. Therefore, giving more attention to develop different Scald management strategies including breeding and screening for Scald resistance varieties, and variety-fungicide combinations is important.

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