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Determination of Sowing Dates, Varieties, and Fungicide Frequency for Managements of Wheat Leaf Blotch (*Zymoseptoria tritici*)

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Abstract: Wheat leaf blotch (*Zymoseptoria tritici*) is economically important foliar disease in major wheat growing areas of Ethiopia. The goal of the current study was to evaluate the effects of sowing dates, varieties, and fungicide frequencies on leaf blotch. In a factorial arrangement of RCBD, four fungicide frequencies with control, three planting dates, and two bread wheat varieties were combined as treatments combination. The highest AUDPC (2502.5) value was scored on the Pavon-76 control treatment at mid –June sowing date during 2020 cropping season, whereas, the lowest AUDPC (290.3) value on the Alidoro variety sprayed four times at early July sowing date during 2021 cropping season. Wheat grain yields were the lowest (0.91t/ha) from unsprayed plots of Pavon-76 susceptible wheat variety during early sowing dates. Alidoro variety treated with three times spray frequencies during late-sowing date produced the highest yield (7.1t/ha). The highest (2776.36$) net benefit was obtained from three times sprayed of Alidoro variety during late June sowing date and the lowest (674.4$) net benefit was obtained from pavon-76 variety without fungicides spray during mid-June sowing date. Therefore, controlling wheat leaf blotch by planting the Alidoro variety at the beginning of July with three fungicide sprays is crucial for Ethiopian farmers. Once more, the wheat pathologist is anticipating additional research including the screening of fungicides and wheat varieties. More study is important to identify the effects of topography and weather on this disease; as well as, the epidemiological study of the pathogen is very important.

Keywords: Effects, Leaf Blotch, Management Practices, Wheat

1. Introduction

Wheat production and productivity around the world is affected by a number of factors including biotic, abiotic stresses, and low adoption of new agricultural technologies [1]. Among the biotic stresses, fungi diseases are the most important factors constraining wheat production [2]. Wheat foliar diseases stem rust, yellow rust, and leaf blotch are the major diseases around the world and across wheat growing regions of Ethiopia [3-5]. The combination of mild temperatures with high humidity, where susceptible varieties are grown on large scale, creates the perfect conditions for the foliar wheat diseases to spread rapidly [6, 7].

The diseases occurs almost in all wheat growing places but its intensity varies from place to place due to variability in weather conditions, differential responses of wheat varieties to the disease and as a result of variations in crop management practices [8].

Wheat leaf blotch caused by the *Zymoseptoria tritici* is the major devastating fungal disease next to stem and yellow rust in Ethiopia [9, 10] and elsewhere in the world [11]. In Ethiopia starting from the first report of leaf blotch [12], the distribution of this disease has been reported [13-15].

Under favorable growing conditions with high relative humidity (85%) and optimal temperature (22°C), leaf blotch could decrease yield by 30 to 70% [16]. In addition to high distribution in our country, it causes up to 82% wheat yield loss [17, 18]. Therefore, some of management options have been recommended to control wheat leaf blotch disease in wheat field. Limiting yield losses can be achieved by planting wheat types with high levels of resistance. Resistance-based materials have been advocated as the primary management strategy for leaf blotch in our country [19-21]. Therefore, Mangudo and EBW174 cultivars were proposed as resistant materials at the adult plant growth stage [20, 10], whilst Danda'a and Ejersa cultivars were suggested as resistant materials at the seedling growth stage [19].

In other countries, cultural methods of management were developed to reduce the pressure of inoculum [16]. These include rotation to non-hosts, field sanitation by deep plowing of crop debris in order to decrease the amount of inoculum available to initiate a new disease cycle. Ababa et al. [13] also suggested that as tillage and crop rotation affects the severity and incidence of *Zt* pathogen. This may be less effective on a field basis due to long-distance dispersal of ascospores, but may be helpful if coordinated within a region [22].

The best method for controlling *Zt* pathogen in wheat is to employ fungicides and resistant cultivars together [23]. This pathogen can be managed by fungicides such as triadimefon, triadimenol, tebuconazole, propiconazole, and epoxiconazole [24]. According to reports, sprays used from the time of the flag leaf through the emergence of the ears were successful in controlling the infection [25, 26] suggested fungicides of various modes of actions are very important to manage this disease. Fungicide use at the right time and rate, together with the adoption of reasonably resistant cultivars, has a significant favorable impact on the control of the leaf blotch disease [27].

However, the effectiveness of sowing dates, fungicides frequency, and varieties on *Zt* pathogen as IDM option have been yet to be achieved under Ethiopian condition even as world. Even though, the effectiveness of sowing date, cultivars, and weather condition on other diseases such as leaf rust and stem rust have been reported so far [28, 29]. As a result there is a need to study those effects and recommend in the areas where the disease is most prevalent and economically important. Thus, this study was designed to contribute towards improved wheat production in Ethiopia through effective and sustainable management of leaf blotch and determine the effects of wheat varieties, sowing dates, and fungicide spray frequencies on leaf blotch disease.

2. Materials and Methods

2.1. Description of Study Areas

The current study was conducted at Holetta Agricultural Research Center during the main cropping season of 2020 and 2021 on station. Holetta is located at altitude of 2400 m. a. s. l, with geographical positions of 09° 40-N and 038° 29 E which is hot spot for leaf blotch disease. The annual rainfall ranges from 0.00-304.1mm and the rainy season is from June to October, with an average of 15.33°C temperature at center and the range was between 6.75°C and 23.91°C [30].

2.2. Treatments and Experimental Design

Susceptible Pavon-76 and moderately resistance Alidoro bread wheat varieties, one time, two times, three times, four times and control (unsprayed) fungicide spray frequency, and Mid-June, Late June, and Early July sowing dates were used as treatments combination. Totally, thirty treatments combination were used in factorial arrangement in randomized complete block design. The fungicide Rex Duo (Epoxiconazole + Thiophanate-methyl) was treated at the rate of 0.5 l /ha in 200L/ha of water. Plot size were 1.2m x 2.5 m = 3m^2 /treatments with a total plot size of 27.4mx12.5m = 342.5 m^2 used. The spacing between plots, rows, and blocks were 1m, 20cm, 1.5m, respectively. Each experimental plot was consisted of 6 rows but, the 4 central rows were used for *Zymoseptoria tritici* disease score. Ten plants per plot were assessed for leaf blotch disease scoring. All cultural and agronomic practices supplemented as per the recommendation to raise the crop.

2.3. Disease Data Collected

$$\text{Disease Incidence:} = \frac{\text{No.of diseased plants x 100}}{\text{Total no.of plants examined}}$$

Disease Severity: The severity of leaf blotch was scored using the scale of double-digit (00–99) as a modification of Saari and Prescott's scale to wheat foliar diseases [31, 16].

Area under Disease Progress Curve (AUDPC): - Area under Disease Progress Curve values were calculated for each treatment by using the equations by Sharma and Duveiller [32] as following.

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

Where,

Xi = the cumulative severity expressed as a proportion at the ith observation, ti = the time (days after planting) at the ith observation and n = total number of observations.

2.4. Assessment of Yield and Yield Components Data

2.4.1. Thousand Kernel Weight (TKW) (g)

One thousand grains were selected at random and weighed in grams for each experimental unit.

2.4.2. Hectoliter Weight (HLW) (Kg/hL)

Grain weight of one-liter volume (random sample) was estimated for each experimental unit by following standard procedure [33] and the result converted to Kg/hL. The moisture content was adjusted at 12.5%.

2.4.3. Grain Yield (GY) (Tones)

Grain yield in gram per plot at 12.5% moisture content was recorded and converted to ton per hectare.

2.5. Cost-Benefit Analysis

The price of wheat grains were computed during January

2021 based on the local market; total price of 0.1 ton was obtained from a hectare basis, costs that vary like cost of fungicide and labor to apply the fungicide was recorded and taken into account. The total amount of these materials (fungicide, seed, labor and water) were used for the experiment computed and its price converted. Before the economic analysis (partial budget) was done, the statistical analysis was conducted to compare the average yield between treated and untreated treatments. The difference between treatments and the economic data were used to do partial budget analysis as follows: Marginal rate of return were calculated using the formula as following.

$$MRR = \frac{DNI*100\%}{DIC}$$

Where, MRR = Marginal Rate of Returns (Cost Benefit Ratio).

DNI = Difference in Net Income compared with the control.

DIC = Difference in Input Cost compared with the control.

2.6. Data Analysis

The source of treatments variation was analyzed by using general linear model. The data was subjected to SAS [34]. Means for treatments compared using least significant difference test (LSD). The partial budget analysis was calculated using the formula established and marginal rate of return was calculated according to CIMMYT [35].

3. Result and Discussion

3.1. Disease Parameters

3.1.1. Disease Severity

Analyses of variance showed that leaf blotch severity between the treatments were significantly different (Tables 1 and 2). In the current study we couldn't find the interaction effects of sowing date, varieties, and fungicides frequencies. However, the mean of leaf blotch double digit data were different when the varieties sowed at different times with different fungicides application frequencies. The highest double digit data of leaf blotch were recorded during the last assessment date on unsprayed plots of two varieties compared with their respective sprayed plots. During 2020 cropping season, the highest disease double digit data (97) was recorded on unsprayed plot of susceptible Pavon-76 variety sowed at mid-June (early sowing date), while the lowest disease double digit data (22) was recorded on four times sprayed plot of early-July sowing date of moderately resistant Alidoro variety (Tables 1 and 2). During 2021 cropping season, the highest disease double digit data (97) was recorded on Pavon-76 variety in unsprayed plots of mid-June sowing date and the lowest disease double digit data (55) was recorded at four times sprayed plots of Alidoro variety at early-July (late sowing date) at fifth assessment date (Table 2).

This result indicates that the control treatments (unsprayed Pavon-76 susceptible variety at mid-June) had the highest leaf blotch double digit data. This is may be due to the leaf blotch pressure is high during mid-June. The plant cultivated during early July indicated that the escape of the plant from the highest inoculum infection and the lowest leaf blotch double digit data were resulted from the four times fungicides (Tables 1 and 2). The current study agrees with various scientists, the planting date has a significant impact on foliar disease [36-38, 22] that crops planted early in the season have a higher risk of infection. In addition to this the leaf rust could be affected by planting date; the lowest disease severity for late disease onset than early disease onset [28]. Early-planted crops are more susceptible to infection. This could be because early-sown plants develop more leaves, which means more inoculums are present [38]. Furthermore, with early-sown crops, the infection has more time to migrate from older to younger leaves due to the slower stem expansion [39, 38].

Among varieties the highest double digit score were recorded on Pavon -76 susceptible variety with mid-June sowing date and in unsprayed plots, whereas, the lowest recorded on moderately resistant variety with early-July sowing date at three and four spray frequencies (Tables 1 and 2). In contrast to this result, the previous report suggested that the powdery mildew was higher AUDPC in late sowing date [2]. Eyal *et al.* [16] showed that the effect of crop resistance level on latent period of *Zt* pathogens and the rate of disease development. Use of resistant variety is the best control strategy of leaf blotch diseases for resource poor farmers in developing countries and the most environmentally friendly and profitable strategy for commercial farmers [40, 14]. Alternatively, this moderately resistant variety can be supplemented with fungicide sprays to minimize leaf blotch development. A current result also reveals that spraying wheat fields could be an effective measure to reduce leaf blotch levels even on susceptible varieties. Moreover, wheat cultivars resistant in one part of the country may display susceptibility elsewhere demonstrating the lack of consistent reaction across locations. This could be attributed to prevailing weather conditions that may affect host resistance to the disease or variation in pathogen populations [26].

The current study shows, the level of disease development was considerably affected by level of fungicide application frequency. The lowest double digit data was recorded on Paven -76 variety when sprayed three times at early July sowing date in both cropping season. Therefore, the farmers should have to use three times fungicide application frequency at early July sowing date to combat this disease. Even though, the application frequency of fungicide data haven't been available; however, different fungicide, and the combination of cultivars and fungicides have been suggested [23, 24].

It is important preserving the effectiveness of succinate dehydrogenase inhibitor (SDHI) based products to reduce the likelihood of severe leaf blotch epidemics [41-43].

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 [44].

Although complete control of leaf blotch development was not achieved and level of control varied across varieties, spraying Rex Duo fungicide frequently significantly reduced the severity level on both varieties. This hastened premature leaves senses along with moisture stress due to low/no rain fall at the later growth stage of the crop could have negative impact on leaf blotch [45].

Among cropping season the highest disease severity was recorded on 2020 cropping season; whereas the lowest recorded on 2021 cropping season even if there is no significant difference b/n seasons. This might be due to more favorable environmental conditions prevailing during the crop growing season; i.e. with rainy, cool and suitable average monthly maximum temperature range of 19°C – 27°C throughout crop growing season. The range of temperature (20°C – 25°C) together with rainy and cloudy condition can best favor infection process of leaf blotch [16].

3.1.2. Area under Disease Progress Curve

Leaf blotch disease area under disease progress curve (AUDPC) across treatments ranged from 689.5 to 2502.5 during 2020 cropping season; whereas ranged from 276.3 to 1940.3 during 2021 cropping season (Tables 1 and 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 [46].

AUDPCs were generally higher on unsprayed plots than on sprayed plots. The maximum values 1940.3 and 2502.5 were recorded on unsprayed plots with mid-June sowing date on variety of Pavon-76; whereas 939 and 2354.3 on Alidoro variety during 2021 and 2020 cropping season, respectively. On the other hand, variety Alidoro sprayed with three times frequencies during early-July sowing date had the lowest (276.3 and 689.5) AUDPC value during 2021 and 2020 cropping season, respectively. All fungicide spray frequency with early-July sowing date have low AUDPC compared to the unsprayed plots with mid-June sowing date but only three and four times Rex Duo sprays significantly reduce AUDPC value, respectively. This agrees with that of the authors [9, 47, 26], who reported maximum AUDPC values from unsprayed plots and the minimum value on highly protected plots.

3.2. Yield and Yield Components

3.2.1. Grain Yield

ANOVA result showed that the grain yield had a significant ($p \leq 0.05$) difference among treatments (Tables 1 and 2). The highest yield (4.3 & 4.99 t/ha) was recorded on Alidoro variety with three and four times Rex Duo sprayed plots during late-June sowing date, respectively during 2020 cropping season. The highest yield (6.4, 6.5 & 7.1 t/ha) was recorded on Alidoro variety two, three and four times Rex Duo sprayed plots during early-July sowing date, respectively during 2021 cropping season. There were significant differences between varieties in both years with respective fungicide frequencies. The lowest yield (0.91 & 1.2t/ha) on Pavon-76 variety unsprayed and one times sprayed plots during mid-June sowing date; whereas 1.98 and 2.05t/ha on Pavon-76 variety with late-June and early-July sowing date, respectively during 2021 cropping season.

In our current research, the highest grain yield was recorded when the Alidoro variety spayed two time at early July sowing date. But, Tadesse *et al.* [26], reported that the highest yield recorded from four times sprayed and the lowest yield from unsprayed during early sowing date. We achieved that the lowest grain yield (0.91t/ha) from untreated Pavon -76 variety at mid-June sowing date in 2021 cropping season. This result was the same with the study of Abera *et al.,* [9]; they reported that the lowest grain yield was obtained from unsprayed variety which averaged from 1.26 to 2.99 t ha^{-1}. The susceptible variety Pavon-76 gave the lower yield than the moderately resistant variety Alidoro, when they weren't treated with fungicide.

3.2.2. Thousand Kernel Weight

The ANOVA result showed that, there were significant differences between treatments in thousand kernels weight (Tables 1 and 2). Thousand kernels weight were highest (45.3g) on Pavon-76 variety with four times sprayed; whereas, the lowest (17.3g) thousand kernel weight on untreated Pavon76 variety at mid-June sowing dates during 2020 and 2021 cropping season, respectively (Table 1). This result was the same with Tadesse *et al.* [26] which reported that Madawalabu variety scored the highest and lowest thousand kernel weight when treated three times and untreated with fungicide.

3.2.3. Hectoliter Weight

There were significant differences between treatments in hectoliter weight. The highest hectoliter weight was recorded on Pavon-76 variety four times sprayed in early-July sowing date in 2021 cropping season; whereas, the lowest hectoliter weight was recorded on the same variety during mid-June sowing date of 2021 cropping season (Tables 1 and 2). This finding is in agreement with the research [15, 26], it is very crucial applying fungicides with recommended frequencies when planting at early sowing date to get the required amount of hectoliter weight components.

Table 1. *Effect of bread wheat varieties, sowing dates and fungicide spray frequencies on yield and yield components at Holetta during 2020/2021 Cropping Season.*

Varieties	Sowing Date	Frequency	Double digit	AUDPC	HLW	TKW	YLD (t/ha)
Pavon- 76	mid June	Unsprayed	97[a]	2503[a]	72[cd]	28[d]	1.3[e]
		One time	81[a-e]	1777[b-f]	78[ab]	40[ab]	2.6[b-e]
		Two times	86[abc]	2018[a-d]	79[ab]	41[ab]	3[a-e]
		Three times	89[ab]	2051[a-d]	78[ab]	41[ab]	3[a-e]

Varieties	Sowing Date	Frequency	Double digit	AUDPC	HLW	TKW	YLD (t/ha)
		Four times	64^{b-g}	1639^{c-g}	79^{ab}	45^{a}	4^{abc}
		Unsprayed	94^{a}	2238^{abc}	74^{bcd}	31^{cd}	2^{cde}
		One time	74^{a-f}	1440^{d-j}	79^{ab}	43^{ab}	3^{a-e}
	Late June	Two times	53^{e-i}	1301^{e-k}	78^{ab}	44^{ab}	3^{b-e}
		Three times	60^{c-h}	1421^{d-j}	79^{ab}	47^{ab}	3^{a-e}
		Four times	64^{b-h}	1505^{d-i}	79^{a}	44^{ab}	4^{ab}
		Unsprayed	74^{a-f}	1612^{c-h}	76^{abc}	37^{bc}	2^{de}
		One time	82^{a-d}	1623^{c-h}	78^{ab}	44^{ab}	4^{a-d}
	Early July	Two times	39^{g-j}	981^{h-l}	79^{ab}	39^{ab}	3^{a-e}
		Three times	36^{ihj}	919^{i-l}	79^{ab}	43^{ab}	3^{a-e}
		Four times	22^{j}	536^{l}	77^{ab}	41^{ab}	3^{a-e}
		Unsprayed	94^{a}	2354^{b}	69^{d}	29^{d}	1.5^{de}
		One time	60^{c-i}	1318^{e-k}	78^{ab}	41^{ab}	2^{b-e}
	Mid June	Two times	81^{a-e}	2022^{a-d}	78^{ab}	40^{ab}	2.7^{b-e}
		Three times	57^{d-i}	1443^{d-}j	71^{cd}	43^{ab}	2.4^{b-e}
		Four times	47^{f-j}	1235^{e-k}	78^{ab}	44^{ab}	2.4^{b-e}
		Unsprayed	86^{abc}	1862^{a-e}	76^{abc}	41^{ab}	3^{a-e}
	Late	One time	75^{a-e}	1619^{c-h}	78^{ab}	41^{ab}	3.2^{a-e}
Alidoro	June	Two times	43^{g-j}	996^{g-l}	78^{ab}	43^{ab}	3.2^{a-e}
		Three times	36^{ih}j	883^{i-l}	79^{ab}	43^{ab}	5^{a}
		Four times	36^{g-j}	791^{jkl}	80^{a}	44^{ab}	4.3^{ab}
		Unsprayed	81^{a-e}	1517^{d-i}	78^{ab}	43^{ab}	3.2^{a-e}
		One time	57^{d-i}	1140^{f-l}	79^{a}	41^{ab}	3.6^{a-e}
	Early July	Two times	53^{e-i}	976^{h-l}	80^{a}	44^{ab}	3.4^{a-e}
		Three times	32^{ij}	689^{kl}	78^{ab}	41^{ab}	3.5^{a-e}
		Four times	39^{g-j}	803^{jkl}	80^{a}	41^{ab}	4.1^{abc}
		Mean	63	1440.4	77.5	40.8	3.01
		CV	26.8	27.9	4.2	11.6	16.8
		LSD	27.7	657.6	5.3	7.7	2.27

Least significant difference Test was used to test the treatments at ($p < 0.05$) AUDPC =Area under disease progress curve, HLW=Hectoliter weight, TKW=thousand kernel weight, YLD=yield.

Table 2. *Effect of bread wheat varieties, sowing dates and fungicide spray frequencies on yield and yield components at Holetta during 2021/2022 Cropping Season.*

Varieties	Sowing Date	Frequency	Severity	AUDPC	HLW	TKW	YLD (t/ha)
		Unsprayed	97^{a}	1940^{a}	63^{b}	17^{h}	1^{p}
		One time	92^{abc}	1401^{bc}	73^{ab}	27^{f}	1^{op}
	Mid June	Two times	81^{b-e}	1130^{cde}	79^{a}	40^{a-e}	2.5^{mno}
		Three times	78^{de}	928^{d-h}	79^{a}	39^{b-e}	3.4^{i-m}
		Four times	78^{de}	1029^{d-g}	79^{a}	40^{a-d}	3^{k-o}
		Unsprayed	92^{ab}	1565^{b}	66^{b}	21^{gh}	2^{nop}
		One time	89^{a-d}	1180^{cd}	73^{ab}	35^{e}	3^{k-n}
Pavon- 76	Late June	Two times	79^{cde}	1130^{cde}	78^{a}	40^{a-e}	4^{e-k}
		Three times	73^{ef}	1133^{cde}	80^{a}	41^{a-d}	4^{d-j}
		Four times	79^{de}	1059^{def}	80^{a}	41^{a-d}	4.6^{d-i}
		Unsprayed	89^{a-d}	1184^{cd}	69^{ab}	24^{fg}	2^{m-p}
		One time	72^{ef}	816^{e-i}	79^{a}	40^{a-e}	4^{f-k}
	Early July	Two times	72^{ef}	770^{f-j}	80^{a}	44^{a}	4^{f-k}
		Three times	62^{fg}	746^{f-k}	80^{a}	44^{ab}	5.5^{b-f}
		Four times	64^{fg}	676^{h-m}	81^{a}	43^{abc}	5^{c-g}
		Unsprayed	82^{b-e}	939^{d-h}	77^{ab}	37^{de}	3.6^{h-l}
		One time	54^{gh}	465^{j-n}	79^{a}	44^{ab}	5^{c-h}
	Mid June	Two times	37^{ijk}	331^{n}	80^{a}	44^{ab}	4^{d-j}
		Three times	40^{ijk}	365^{mn}	80^{a}	43^{abc}	5.5^{b-f}
		Four times	43^{hij}	491^{j-n}	80^{a}	44^{ab}	5.3^{b-g}
		Unsprayed	72^{ef}	706^{g-l}	78^{a}	38^{cde}	5.5^{b-f}
Alidoro		One time	53^{gh}	430^{k-n}	79^{a}	43^{ab}	5.3^{b-g}
	Late June	Two times	44^{hij}	432^{k-n}	80^{a}	43^{abc}	6^{abc}
		Three times	43^{hij}	462^{j-n}	80^{a}	43^{ab}	6^{abc}
		Four times	43^{hij}	473^{j-n}	80^{a}	43^{abc}	5.5^{b-e}
		Unsprayed	71^{ef}	759^{f-k}	76^{ab}	35^{e}	5^{c-g}
	Early July	One time	47^{hi}	390^{lmn}	79^{a}	43^{abc}	6.4^{ab}
		Two times	36^{ijk}	388^{lmn}	80^{a}	44^{ab}	7^{a}

Varieties	Sowing Date	Frequency	Severity	AUDPC	HLW	TKW	YLD (t/ha)
		Three times	33[jk]	276[n]	79[a]	44[ab]	6.5[ab]
		Four times	30[k]	290[n]	80[a]	43[abc]	5.5[bcd]
		Mean	64	798	76	39	4
		CV	10.5	23.2	9.06	7.4	18.6
		LSD	13	334.8	11.4	4.7	1.4

Least significant difference Test was used to test the treatments at ($p < 0.05$) AUDPC =Area under disease progress curve, HLW=Hectoliter weight, TKW= thousand kernel weight, YLD=yield

3.3. Cost Benefit Analysis

Partial budget analysis indicated that four times fungicide spray frequencies had the highest total cost while the unsprayed plots had the lowest cost on both varieties (Table 3). On the other hand, all fungicide spray frequencies were used on the two varieties gave high gross field benefit and marginal rate of return when compared to untreated. During 2020 cropping season on variety Alidoro, the partial cost benefit analysis showed that the maximum total gross yield benefit 3,789.9$ per hectare was obtained from three times spray frequencies during late-June sowing date. Variation in net benefit was observed among the two varieties (Table 3). During 2020 cropping season, the highest net profit of 3,690.9 $ per hectare was obtained at marginal rate of return (MRR) of 3,831.2% when Alidoro variety sprayed three times at late-June sowing date (Table 3). During 2021 cropping season on variety Alidoro, the partial cost benefit analysis showed that the maximum total gross yield benefit 6,291.1$ per hectare was obtained from three times spray frequencies during early-July sowing date (Table 4). The highest net profit of 6,204.9$per hectare at marginal rate of return (MRR) 7,192.4% was recorded when Alidoro variety sprayed two times at early-July sowing date. This finding is in agreement with the research [15, 26], the highest (3013%) and lowest (0%) marginal rate of return was obtained from Madawalabu variety with two time fungicide spray and from all unsprayed fields, respectively in Ethiopia [26]. Slafer and Satorre [48] 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 [49]. However, farmers would refrain from using fungicides unless proven effective and profitable.

Table 3. *Partial budget analysis for the management of wheat Zymoseptoria tritici during the main cropping season of 2020/21 at HARC.*

Varieties	Sd	F	Y	WSP	SR	TIC	MC	NB	MB	MRR (%)
Pavon-76	Early (Mid June)	Unsprayed	1.3	759.5	957.0	60.4	0.0	896.5	0.0	0.0
		One time	2.6	759.5	1974.7	73.3	12.9	1901.4	1004.8	7801.7
		Two times	3.0	759.5	2308.9	86.2	25.8	2222.7	1326.1	5148.2
		Three times	3.2	759.5	2460.8	99.1	38.6	2361.7	1465.2	3791.9
		Four times	3.9	759.5	2962.0	111.9	51.5	2850.1	1953.5	3791.9
	Mid (Late June)	Unsprayed	1.9	759.5	1458.2	60.4	0.0	1397.8	0.0	0.0
		One time	3.2	759.5	2453.2	73.3	12.9	2379.9	982.1	7624.8
		Two times	2.7	759.5	2050.6	86.2	25.8	1964.4	566.6	2199.8
		Three times	3.2	759.5	2392.4	99.1	38.6	2293.3	895.5	2317.7
		Four Times	4.2	759.5	3189.9	111.9	51.5	3077.9	1680.1	3261.2
	Late (Early July)	Unsprayed	1.9	759.5	1412.7	60.4	0.0	1352.2	0.0	0.0
		One time	3.6	759.5	2734.2	73.3	12.9	2660.9	1308.6	10160.4
		Two times	3.2	759.5	2460.8	86.2	25.8	2374.6	1022.3	3968.8
		Three times	2.9	759.5	2172.2	99.1	38.6	2073.1	720.9	1865.6
		Four times	2.9	759.5	2202.5	111.9	51.5	2090.6	738.4	1433.2
Alidoro	Early (Mid June)	Unsprayed	1.5	759.5	1108.9	60.4	0.0	1048.4	0.0	0.0
		One time	2.7	759.5	1640.5	73.3	12.9	1567.2	518.8	4027.8
		Two times	1.0	759.5	2020.3	86.2	25.8	1934.1	885.6	3438.1
		Three times	2.4	759.5	1822.8	99.1	38.6	1723.7	675.3	1747.7
		Four Times	2.4	759.5	1815.2	111.9	51.5	1703.2	654.8	1271.0
	Mid (Late June)	Unsprayed	3.0	759.5	2270.9	60.4	0.0	2210.5	0.0	0.0
		One time	3.2	759.5	2400.0	73.3	12.9	2326.7	116.2	902.5
		Two times	1.0	759.5	2438.0	86.2	25.8	2351.8	141.3	548.7
		Three times	5.0	759.5	3789.9	99.1	38.6	3690.8	1480.3	3831.2
		Four Times	4.3	759.5	3265.8	111.9	51.5	3153.9	943.4	1831.2
	Late (Early July)	Unsprayed	3.2	759.5	2392.4	60.4	0.0	2332.0	0.0	0.0
		One time	3.6	759.5	2734.2	73.3	12.9	2660.9	328.9	2553.6
		Two times	3.4	759.5	2551.9	86.2	25.8	2465.7	133.7	519.2
		Three times	3.0	759.5	2635.4	99.1	38.6	2536.4	204.4	529.0
		Four Times	4.1	759.5	3091.1	111.9	51.5	2979.2	647.2	1256.3

Sd, Sowing date; F, Frequencies; Y, yield (t/ha); WSP, wheat selling price (dollar/ton); Sale revenue (dollar/ha); TIC, total input cost (dollar/ha); MC, marginal cost (dollar/ha); NB, net benefit (dollar/ha); MB, marginal benefit (dollar/ha); MRR, marginal rate of return (%)

Table 4. *Partial budget analysis for the management of wheat STB during the main cropping season of 2021/22 at HARC.*

Varieties	Sd	F	Y	WSP	SR	TIC	MC	NB	MB	MRR (%)
		Unsprayed	0.9	886.1	806.3	60.4	0.0	745.9	0.0	0.0
		One time	1.2	886.1	1063.3	73.3	12.9	990.0	244.1	1895.1
	Early (MidJune)	Two times	2.5	886.1	2188.6	86.2	25.8	2102.4	1356.5	5266.1
		Three times	3.4	886.1	2977.2	99.1	38.6	2878.1	2132.2	5518.2
		Four times	2.9	886.1	2551.9	111.9	51.5	2439.9	1694.1	3288.2
		Unsprayed	2.0	886.1	1754.4	60.4	0.0	1694.0	0.0	0.0
		One time	3.2	886.1	2817.7	73.3	12.9	2744.4	1050.4	8155.5
Pavon-76	Mid (Late June)	Two times	4.2	886.1	3686.1	86.2	25.8	3599.9	1905.9	7398.8
		Three times	4.3	886.1	3810.1	99.1	38.6	3711.1	2017.1	5220.1
		Four Times	4.6	886.1	4067.1	111.9	51.5	3955.1	2261.0	4388.7
		Unsprayed	2.1	886.1	1816.5	60.4	0.0	1756.0	0.0	0.0
		One time	4.1	886.1	3650.6	73.3	12.9	3577.3	1821.3	14140.8
	Late (Early July)	Two times	4.0	886.1	3500.0	86.2	25.8	3413.8	1657.8	6435.6
		Three times	5.5	886.1	4838.0	99.1	38.6	473890.5	2982.9	7719.6
		Four times	5.0	886.1	4439.2	111.9	51.5	4327.3	2571.3	4990.9
		Unsprayed	3.6	886.1	3163.3	60.4	0.0	3102.9	0.0	0.0
		One time	4.8	886.1	4288.6	73.3	12.9	4215.3	1112.4	8637.1
	Early (MidJune)	Two times	4.3	886.1	3810.1	86.2	25.8	3723.9	621.1	2411.1
		Three times	5.5	886.1	4838.0	99.1	38.6	4738.9	1636.0	4234.0
		Four Times	5.3	886.1	4696.2	111.9	51.5	4584.3	1481.4	2875.4
		Unsprayed	5.5	886.1	4846.8	60.4	0.0	4786.4	0.0	0.0
		One time	5.3	886.1	4660.8	73.3	12.9	4587.4	-199.0	-1544.7
Alidoro	Mid (Late June)	Two times	6.0	886.1	5316.5	86.2	25.8	5230.3	443.9	1723.1
		Three times	6.1	886.1	5405.1	99.1	38.6	5306.0	519.6	1344.7
		Four Times	5.5	886.1	4873.4	111.9	51.5	4761.5	-24.9	-48.4
		Unsprayed	5.0	886.1	4412.7	60.4	0.0	4352.2	0.0	0.0
		One time	6.4	886.1	5670.9	73.3	12.9	5597.6	1245.3	9669.0
	Late (Early)	Two times	7.1	886.1	6291.1	86.2	25.8	6204.9	1852.7	7192.4
		Three times	6.5	886.1	5759.5	99.1	38.6	5660.4	1308.2	3385.6
		Four Times	5.54	886.1	4908.9	111.9	51.5	4796.9	444.7	863.2

Sd, Sowing date; F, Frequencies; Y, yield (t/ha); WSP, wheat selling price (dollar/ton); Sale revenue (dollar/ha); TIC, total input cost (dollar/ha); MC, marginal cost (dollar/ha); NB, net benefit (dollar/ha); MB, marginal benefit (dollar/ha); MRR, marginal rate of return (%)

4. Conclusion and Recommendation

Wheat foliar disease such as Stem rust, Yellow rust, and leaf blotch caused by *Zymoseptoria tritici* are the major diseases around the world and across wheat growing regions of Ethiopia. The unsprayed plot of Pavon-76 variety with mid-June sowing date showed significantly higher 97double digit, while four times sprayed plot of Alidoro variety with early-July sowing date showed significantly lower 29 double digit. Among varieties the highest double digit was recorded on susceptible Pavon -76 variety; whereas, the lowest was recorded on moderately resistant Alidoro variety. From sowing dates the highest double digit was recorded on mid-June sowing date; while, the lowest double digit was scored on early-July sowing date. Among fungicide spray frequencies the highest double digit was scored on unsprayed plots; whereas, the lowest double digit was recorded on three times and four times spray frequencies. All fungicide spray frequency reduced AUDPC compared to the unsprayed plots with mid-June sowing date. Grain yield showed a significant ($p \leq 0.05$) difference among treatments. The highest yield was recorded on Alidoro variety with two and three times sprayed at late-June sowing date, respectively.

The highest marginal rate of return (MRR) was recorded from Pavon-76 variety with one time spray on three sowing date during 2020 cropping season. Generally; it is important the early-July sowing with 3 times spray frequencies to manage economically the leaf blotch disease on susceptible Pavon-76 wheat variety. It needs further study to confirm the weather and topographic factors to affects this disease. The more study on the epidemiology, fungicide screening and wheat materials screening for this disease is very important.

Declarations

Author Contribution Statement

Yitagesu Tadesse and Asela Kesho: Designed and performed the experiment, analyzed and interpreted the data and also wrote the paper.

Data Availability Statement

All data available was used for this article.

Declaration of Interest's Statement

The authors declare no conflict of interest.

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