Journal of Plant Sciences
2024, Vol. 12, No. 6, pp. 182-190
https://doi.org/10.11648/j.jps.20241206.12

Research Article

The Effect of Variety and Fungicide Application on Yellow Rust (*Pucciniastriiformis*f.sp*tritici*) Disease of Bread Wheat (*Triticumaestivum*L.) in East *Gojjam,* Ethiopia

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Abstract

The study was conducted to evaluate effects of bread wheat variety and fungicide application on yellow rust epidemics under natural field conditions at Debre Markos University research site, East Gojjam Zone in the main cropping season of 2021/2022 year. Three different fungicides (Tilt (25EC), Natura (250 EW), and Takeoff (293 SC) including fungicide unsprayed combined with five improved wheat varieties (Honkolo, Wane, Liben, Lemu and Kakaba) were used in the experiment and the experiment was laid out in RCBD design with factorial arrangement and replicated three time. Disease data's (severity, AUDPC, incidence and grain yield were recorded. The maximum disease incidence (100 %), initial and final disease severity (39.75 at 57 DAP and 66.66% at 78 DAP) and AUDPC (1770.71 %-day) recorded from fungicide unsprayed plot on Honkolo variety. But the lowest disease incidence (1.50 %), initial and final severity (1.89 % at 57 DAP and 2.36 % at 78 DAP) and AUDPC (78.93 % - day) were recorded from the combination of Liben variety with Natura (250% EW) fungicide treatment. Moreover, the maximum grain yield (6.00 t/ha) was obtained from combination of Kakaba variety and Natura (250 EW) fungicide treatment plot. While the minimum yield (3.00 t/ha) was recorded from fungicide unsprayed Honkolo variety. Natura (250 EW) fungicide sprayed varieties were effective to against yellow rust and gave the highest values of yield over unsprayed plots and other fungicides application. However, Combination of Kakaba variety and Natura (250 EW) fungicide application was more feasible than other treatments.

Keywords

AUDPC, Bread Wheat, Grain Yield, Incidence, Severity, Yellow Rust

1. Introduction

Wheat is belongs to the Poaceae family, tribe Triticeae and it is one of the most important cereals crops in the world, with an area of cultivation that is larger than any other cereal crop and a large quantity of grain produced [33]. This grain is an important industrial and food crop and ranks second among the most important cereal crops in the world. It is the top cereal grain and used by more than one third of the world's population as a staple food. It grew at a wider range from 1500 to 3000 meters above sea level [12]. The most suitable agricultural-economic zones for wheat production

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Received: 11 September 2024; **Accepted:** 8 October 2024; **Published:** 11 November 2024

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range from 1900 to 2700 m.a.s.l [51]. The total production volume of wheat is 772.64 million metric tons on more than 240 million ha in the world [21].

Wheat is used in the production of traditional and modern processed foods, such as injera, bread and other industrial products like pasta and macaroni [49]. Moreover, wheat straw is commonly used as a roof tacking material and as a feed for animals. Wheat grains are good source of minerals, fibers, protein and antioxidants which recommended for health purpose [29].

The major wheat-producing countries in the world are China, India, the USA, Russia, France, Canada, Germany, Pakistan, and Australia [48]. Wheat producing countries in Sub-Saharan Africa are Egypt, Ethiopia, South Africa, Sudan, Kenya, Tanzania, Nigeria, Zimbabwe, and Zambia in descending order [47]. As [27] indicated, Ethiopia is one of the largest wheat producers subsequently to Egypt in Sub Sahara Africa in terms of total wheat area cultivated and total production [2]. The national production volume of wheat is 2.83 million metric tons [24]. In spite of the production and yield increases, average grain yield of wheat is still low (< 1.68 t/ha) highly variable and below the world's average (3.54 t/ha). It ranks third in area coverage after teff and maize and second in terms of grain production next to maize [7].

Despite its importance as food and industrial crop, wheat production and productivity around the globe is hampered by a number of factors including biotic and abiotic stresses as well as low adoption of new agricultural technologies. Of the biotic stresses, diseases caused by fungi are the most important factors constraining wheat production. Septoria diseases (*Septoriatritici blotch*), stem rust (*P. graministritici*), leaf rust (*P. triticina*) and Yellow rust (*Pucciniastriiformis*f.sp. *tritici*) are prevalent throughout the country [28, 9].

Yellow rust disease is the most sever and destructive disease that cause reduction of wheat yield production and becoming more occurring often in midland and highland altitudes of Ethiopia [6]. However, the prevalence and severity of the disease is more dependent on weather conditions of the season and varieties grown. The combination of mild temperatures with high humidity in areas, where susceptible wheat varieties are grown on large scale, creates the perfect conditions for yellow rust (*Pucciniastriiformis*f.sp*tritici*) to spread rapidly. The impact of yellow rust (*Pucciniastriiformis*f.sp*tritici*) on a particular cultivar is vary depending on the cultivar's susceptibility, the rate of the development and its duration [32, 42]. In Ethiopia, yellow rust can cause yield losses of up to 100% on susceptible cultivars if infection occurs very early in the crop development stage and the disease continues to develop during the growing season [45]. Based on regional state of Ethiopia the highest wheat yield loss by yellow rust recorded in *Amhara* region which was 50% [47]. [52] Indicated that 32% of wheat grain yield loss observed in East*Gojam Zone* including the study area.

Disease management options are recommended to control *Pucciniastriiformistiritici*in wheat fields. Among these, Cultural methods provide strategy to partially control wheat stripe rust. Using a series of cultural practices significantly enhances the existing sources of resistance. As a result, crop management in terms of a combination of crop choice, timing of seeding and removing volunteer cereals may control inoculums of yellow rust [48, 21]. This may be less effective on a field basis due to long-distance dispersal of uredinospore and aeciospores of the *Pucciniastriiformistiritici*. Resistance in wheat to *Pucciniastriiformistiritici*has been demonstrated by a number of researchers, and breeding for resistance is likely to be the most practical method of controlling *Pucciniastriiformistiritici* [20].

Several sources of resistance have been reported but breeding for resistance has not always been successful in protecting wheat from the damaging effects of the disease. Most yellow rust outbreaks happen soon after they are released, because they are often caused by the introduction of new races or changes in environmental factors [36, 17]. Widespread use of resistance varieties under wheat production systems became susceptible to yellow rust disease because of their low resilience. Fungicides of various modes of actions have been recommended to manage *Pucciniastriiformistiritici* but their use in Ethiopia has been limited mainly due to economic reasons [13]. Farmers used the same fungicides extensively to reduce the effect of yellow rust disease aggressiveness on wheat yield loss under field conditions for several years. This creates suitable condition for the adaptation and development of the disease despite look after their field and economic loss [37]. Moreover, [39], report that the use of fungicides has led to the development of resistance by the *Pucciniastriiformistiritici*.

Many reports have indicated that integrating different varieties of plants and fungicides can help to manage diseases by recognizing and reacting to them differently and this can be helpful in suppressing disease development. The performance of varieties may vary depending on the fungicides used, which is probably due to the active ingredients in the product formulation and the pathogen itself [10, 38]. Besides the benefits of reducing yield losses from diseases, the combined uses of fungicide with resistance varieties can also contribute to trim down the health risks associated with high fungicide applications, reduce the need of application of high fungicide and able to diminish the risk to human health, environmental contamination and rise the economic benefit of farmers [16]. A good combination of variety and fungicide will definitely be preferred than a variety that demands no or little fungicidal activity [8, 14]. However, this alternative option for management of yellow rust not has been evaluated in the study area. Therefore the objectives of this study were to evaluate the effects of variety and fungicide application on yellow rusts disease and grain yield of bread wheat under natural field conditions.

2. Material and Methods

2.1. Description of Study Area

Field experiment was conducted at major wheat growing area at Debre Markos University research site, in East *Gojjam Zone*, Ethiopia in the main cropping season in 2021. It far away 265 Km from Bahirdar and 304 Km from Addis Ababa. The area is selected based on wheat production potentials and hot spot for the occurrences of yellow rust disease on wheat. Debre Markos University is geographically located at 10° 19 □ 43 □ latitude North and 37°44□43 □ longitude East, with an altitude of 2,446 m.a.s.l. The minimum and maximum temperatures are 11 ℃ and 25 ℃, respectively. Annual average rainfall was 1,628 mm during 2021. The soil of the experimental area was dominated by Nitosols with a PH value of 5.6 (moderately acidic).

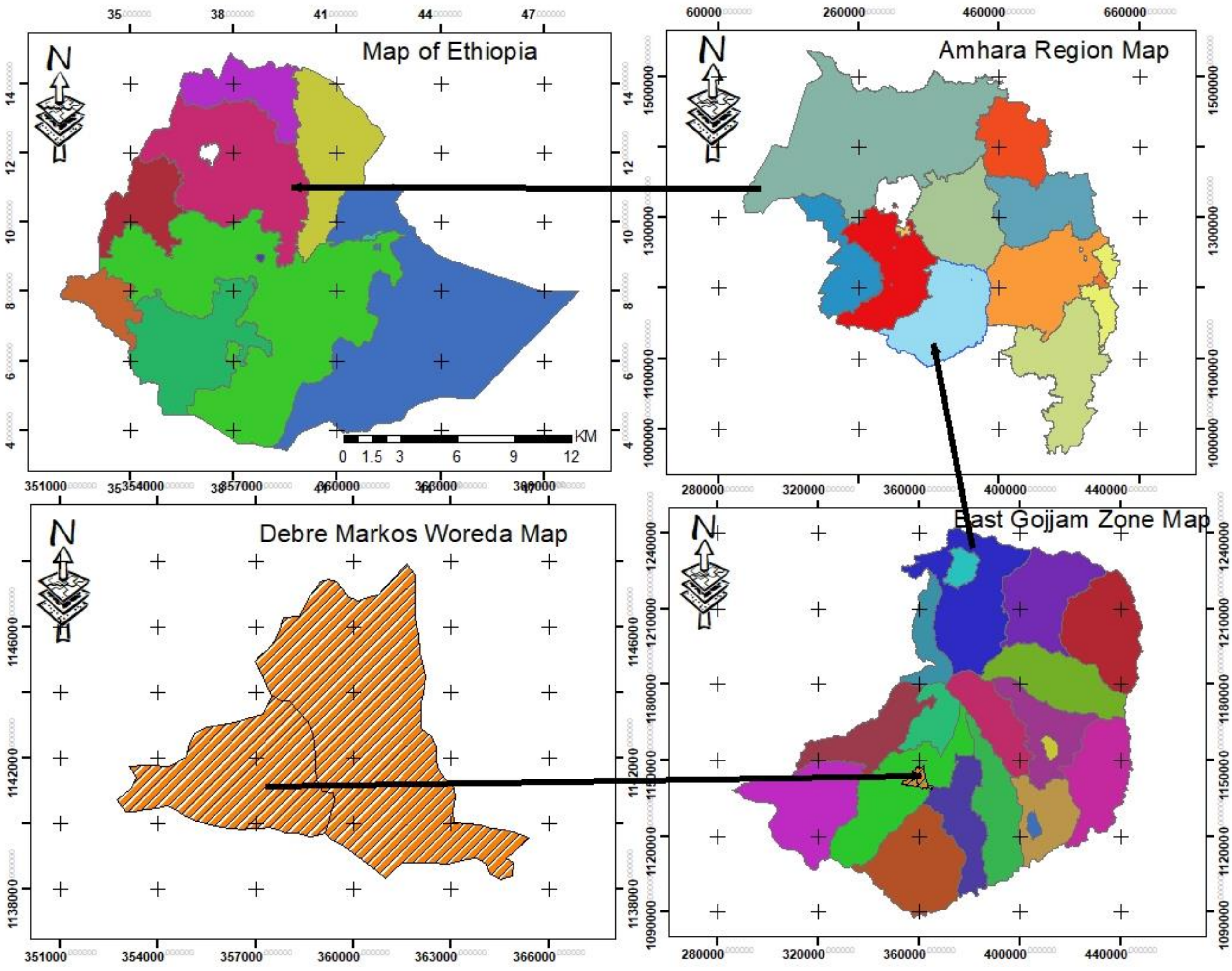

Figure 1. *Map of Debre Markos district.*

2.2. Treatments and Experimental Design

Five wheat varieties (Kakaba, Honqolo, Liben, Lemu, and Wane) and three fungicides (Tilt (25 EC), Natura (250EW) and Takeoff (293 SC) and unsprayed (control) were used in the experiment. Five different levels of wheat varieties were obtained from different Ethiopian Agricultural Research Centers (EARC). A randomized complete block design with three replications was employed in a factorial arrangement.

Each wheat variety (Kakaba, Honqolo, Liben, Lemu, and Wane) were randomly combined with one of the three fungicides (Tilt 25 EC), Natura (250 EW) and Takeoff (293 SC) and unsprayed as a control were included for all varieties. The treatments were assigned randomly to experimental plots within a block. The size of the experimental plot was 1.6 m X 2 m (3.2 m^2) consisting of eight rows with six harvested rows. The space between rows, plots and blocks were 0.2 m, 1.5 m and 2 m, respectively. Seeds of each wheat variety were sown at a rate of 150 kg ha^{-1} on a well-prepared plots and seeds were sown manually (hand drill) in rows.

The fungicides were applied based on the recommendation rate of the manufacturers using a manual knapsack sprayer of 20 litter capacity and applied as soon as the first disease symptoms were observed on the foliage at seven days interval for four weeks. To minimized fungicidal drifts effect between treatments during spraying, plots were protected with polyethylene sheets, which had 1.5 m high on all sides of the plot. Unsprayed plots were left for every variety as control to permit maximum development of disease epidemics.

NPSB (nitrogen phosphorus sulfur boron) called Blended fertilizer and Urea fertilizers were applied at the rate of 200 kg ha^{-1} and 322 kg ha^{-1} respectively. The total amount of NPSB (Blended) fertilizer was applied during sowing and Urea was applied two times 1/3 of urea fertilizer were applied at the time of seed sowing and the remains 2/3 of urea was applied after 35 days of seed sowing. The seed rate of each bread wheat varieties was 150 kg ha^{-1}. All other agronomic practices were applied based on recommendations for wheat crop production (Amhara region wheat crop production improvement package, 2015).

2.3. Data Collection and Analysis

Disease severity data was recorded by visually observations of the proportion of infected plant part according to Modified Cobbs scale, (1948) (Mahmoud *et al*., 2015). Severity data was taken starting from the appearance of the sign or symptoms to physiological maturity of the crop on15 randomly selected pre-tagged plants in the central six rows of each plot. Each plant with in each plot was visually evaluated for percent foliar infection (severity) at 7 days interval as soon as the occurrence of disease symptom. Severity on leaves was rated using 1-9 scales. 1 represents no visible symptoms and 9 represents disease coverage more than 80 % o foliar tissue. Disease severity scores were converted in to percentage severity index (PSI) for analysis.

$$\mathrm{PSI} = \frac{Snr \times 100}{Nps \times Msc}$$

Where Snr is sum of numerical rating, Nps is number of plants scored and Msc is the maximum score on the scale.

In addition disease incidence data was recorded on each experimental plot by counting number of diseased plants from 30 randomly taken plants of six rows and calculated at the proportion of the diseased plants over the total stand count (30 plants) at 105 days after seed sown and calculated using the formula suggested by [15].

$$\text{Disease incidence(\%)} = \frac{\text{Number of infected plant}}{\text{Total number of plant}} \times 100$$

Area under disease progress curve calculated using the coefficient of infection values from the first rust severity data by using the subsequent formula [15].

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

Where: X_i and X_{i+1} are the values of two consecutive severity assessments, and t_i and t_{i+1} are the dates of the two consecutive assessments. Its measurement unit of AUDPC is (%-day).

Grain yield was recorded in gram per plot at 12.5% moisture content and translated to t/ha. Only six of the internal rows of the plots were harvested for yield and biomass estimations, excluding 0.5 m on both sides along the length of the plot, and the net plot area was 1.4 m^2.

The mean value of disease incidence, disease severity, AUDPC and grain yield of bread wheat were subjected to GLM analysis of variance (ANOVA) to evaluate treatments effect using SAS computer package version 9.2 (SAS Institute Inc., 2008 version). Means for different fungicides and varieties combinations were compared using Fisher's list significant different at 5% (LSD 5 %).

3. Result and Discussion

3.1. Time of Disease Occurrence on Bread Wheat

In the study area (Experimental site) yellow rust disease was appeared Kakaba, Honkolo, Lemu, Wane and Liben were recorded at 57, 64, 71 and 78 days after seed sowing respectively. Kakaba, Honkolo and Lemu varieties were infested by yellow rust more than other varieties due to their ability to allow the entry, establishment and reproduction of the pathogen (Table 1). The variation was happened due to the overcoming of varieties resistance gene by virulence gene of yellow rust and the presence of resistance gene on resistance varieties to against the entrance and establishment of yellow rust pathogen. Similarly [19, 38, 50] who worked on bread wheat showed that yellow rust was onset at tiller and early flowering stage in relation to the growth stage on the highly susceptible varieties than moderately resistance and resistance varieties. [23, 26, 37] reported that, yellow rust is a series wheat disease occurring when it gets favorable environmental condition and susceptible host.

3.2. Disease Incidence

Moreover, the interaction of fungicide and wheat variety was also highly significantly (Table 1) affected the disease incidence. Highest yellow rust incidences (100 %, 98.88 % and 97.77 %) were recorded from fungicide unsprayed plots of Honkolo, Lemu and Kakaba. But the lowest yellow rust incidence (1.50 %) was observed on Liben variety and

Natura (250 EW) fungicide combination. The interaction of variety and fungicide application reduced disease incidence more than the main effect of variety and fungicide application [4, 5, 41].

This result indicated that interaction of resistance variety and effective fungicide application was the most important management mechanism of yellow rust disease than the use of variety or fungicide application alone. The result corresponding to [30, 37, 43] relatively better results in the management of the yellow rust were obtained from the use of varieties having different levels of resistance to rust diseases with Rex® Dou and Natura 250 EW right after the appearance of the disease symptoms. However, unsprayed plots of all varieties showed the highest rust incidence, severity and AUDPC and provided minimum grain yield as compared to the sprayed ones.

3.3. Disease Severity

The interaction effect of variety and fungicide application on the occurrence of yellow rust severity was highly significantly difference (Table 1). The fungicides application reducing disease development effectively on Honkolo, Lemu and Kakaba varieties as compared to others two varieties (Wane and Liben). The highest (39.75%) and the lowest (1.89 %) initial disease severity at 57 DAP were recorded from unsprayed Honkolo and Liben varieties combined with Natura (250 EW) fungicide application plots respectively (Table 1).

The highest (61.66 %) and the lowest (2.36 %) final disease severity recorded at 78 DAP from unsprayed Honkolo and combination of Liben variety and Natura (250 EW) fungicide (Table 1). This indicates that different fungicide-variety combinations reduced yellow rust severity as compared to unsprayed susceptible variety. This was due to the genetic makeup of the variety and the effectiveness of fungicide to against the development of the yellow rust. The difference in the extent of yellow rust severity exhibited due to the effect of variety and fungicide application on the disease development.

The current result lines with [35, 38, 46] who worked on management of wheat yellow and stem rust stated that the use of variety in combination with fungicide application reduced yellow and stem rust. He explained that the new fungicide Natura (250EW) and Rex Dou protects better than other fungicides due to the responsible of active substances incorporated in the product formulation, and wheat varieties having different levels of resistance gene to yellow rust disease supplemented with fungicide application in decreasing disease suppression that might delay inoculums blowout and disease progress. It creates favorable growing condition for wheat growth.

Likewise [6, 40, 44] described that the highest disease severity was observed on the susceptible varieties which were not sprayed by fungicides and less severity observed on the susceptible wheat varieties sprayed by fungicides and/or resistance varieties which were sprayed and/or unsprayed by fungicides. Similarly [25, 31, 34] stated that proper application of fungicide was made, complete control of stripe rust of wheat was achieved in super susceptible cultivars such as Galama variety.

3.4. Area Under the Disease Progress Curve (AUDPC)

The interaction of fungicides and wheat variety was also the highly and significantly affected AUDPC value (Table 1). The highest (1770.70 %-day) AUDPC and the lowest AUDPC value (78.93%-day) were recorded from fungicide unsprayed Honkolo variety and combination of Liben variety and Natura (250 EW) fungicide application. The result indicated that wheat varieties which have no resistance gene and not sprayed by fungicides extremely suffered by yellow rust and exhibit high AUDPC value. Even though, yellow rust affected moderately resistance varieties through overcoming the resistance gene of variety by developing new virulence gene unless sprayed by fungicides. Integration of varieties, especially moderately resistance, moderately susceptible and susceptible varieties and effective fungicide application abridged AUDPC of yellow rust. This result agreed with [3, 18, 43] reported that the interaction of variety and fungicide interaction manages fungal disease than using variety or fungicide separately.

3.5. Grain Yield of Wheat

Moreover, wheat grain yield was highly and significantly affected by the interaction of varieties and fungicides application (Table 1). The maximum grain yield (6.00 t/ha) was recorded from combination of Kakaba variety and Natura (250 EW) fungicide application. However the minimum grain yield (3.00 t/ha) was recorded from fungicide unsprayed Honkolo variety. This implies susceptible varieties were exposed for yellow rust disease than moderately resistance and resistance varieties unless fungicide application. Similarly, [1, 11, 22, 47] stated that the pathogen influenced the leaf area in the susceptible varieties and diminished the above ground biomass, seed weight and grain yield of wheat.

Table 1. *Effect of variety and fungicide application on yellow rust and grain yield of bread wheat.*

Trt		**Incid**	**PSI 57 DAP**	**PSI 64 DAP**	**PSI 71 DAP**	**PSI 78 DAP**	**AUDPC**	**GY(t/ha)**
Variety	Fungicide							
Honkolo	Unsprayed	100.00^{a}	39.75^{a}	47.17^{a}	50.33^{a}	61.66^{a}	1770.71^{a}	3.00^{h}
	Tilt	11.09^{b}	33.50^{b}	38.56^{b}	39.00^{b}	44.35^{b}	1378.58^{b}	4.78^{bcde}
	Natura	4.42^{efgh}	17.42^{e}	18.83^{d}	19.50^{f}	21.73^{f}	683.84^{e}	5.50^{b}
	Takeoff	8.89^{bcd}	19.87^{d}	20.92^{d}	22.83^{e}	25.83^{e}	789.66^{d}	5.36^{bc}
Wane	Unsprayed	6.67^{cdef}	3.5^{j}	4.01^{h}	4.60^{i}	4.91^{ijk}	153.24^{i}	4.05^{ef}
	Tilt	3.30^{fghi}	2.0^{j}	2.08^{h}	2.41^{i}	2.56^{jk}	82.72^{i}	4.69^{cde}
	Natura	2.10^{i}	2.06^{j}	2.15^{h}	2.28^{i}	2.45^{jk}	81.87^{i}	5.10^{bc}
	Takeoff	2.20^{hi}	2.05^{j}	2.16^{h}	2.46^{i}	2.46^{jk}	82.08^{i}	4.81^{bcde}
Liben	Unsprayed	3.30^{fghi}	2.05^{j}	2.43^{h}	2.33^{i}	2.55^{jk}	83.07^{i}	4.10^{ef}
	Tilt	2.22^{ghi}	2.05^{j}	2.26^{h}	2.43^{i}	2.40^{jk}	80.68^{i}	4.24^{def}
	Natura	1.50^{i}	1.89^{j}	22.16^{h}	2.23^{i}	2.36^{jk}	78.93^{i}	5.00^{bcd}
	Takeoff	2.20^{hi}	2.05^{j}	2.41^{h}	2.46^{i}	2.48^{jk}	79.91^{i}	4.90^{bcd}
Lemu	Unsprayed	98.88^{a}	18.85^{ed}	21.17^{d}	26.00^{d}	30.33^{d}	864.56^{d}	3.14^{gh}
	Tilt	7.78^{bcde}	13.00^{f}	15.00^{e}	16.33^{g}	19.16^{g}	565.83^{f}	3.88^{fg}
	Natura	4.42^{efgh}	6.41^{i}	7.58^{g}	8.33^{h}	8.75^{j}	280.00^{h}	3.88^{fg}
	Takeoff	5.55^{defg}	6.83^{hi}	7.80^{g}	9.00^{h}	9.83^{j}	300.65^{h}	4.64^{cedf}
Kakaba	Unsprayed	97.77^{a}	25.32^{c}	28.50^{c}	34.00^{c}	40.00^{c}	1143.92^{c}	3.10^{h}
	Tilt	9.99^{bc}	10.50^{g}	11.50^{ef}	13.83^{g}	16.58^{h}	467.25^{g}	5.00^{bcd}
	Natura	4.42^{efgh}	8.00^{hi}	9.20^{fg}	9.66^{h}	10.83^{ij}	338.33^{h}	6.00^{a}
	Takeoff	5.55^{defg}	8.67^{hg}	9.33^{fg}	9.75^{h}	12.66^{i}	348.83^{h}	5.26^{bc}
F test		****	****	****	****	****	****	***
CV (%)		11.38	10.02	16.76	10.88	9.48	11.11	8.9
LSD		3.50	1.87	3.53	2.52	2.53	90.79	0.0051

Note: **** = highly significant different, AUDPC=Area under the disease progress curve, CV = Coefficient of variance, DAP =Date after planting, Grain yield, Incid = incidence. LSD = list significant different at 5%, PSI = Percentage of severity index, Trt= treatment

4. Conclusion

All five wheat varieties supplemented with foliar spray fungicides had distinct effect in reducing yellow rust disease epidemics at the study area. However, the integration of Liben varieties with Natura fungicide significantly reduced the intensity of yellow rust disease of wheat. At the final date of assessment Liben and Wane variety combined with Natura showed lower disease incidence. The lowest of disease severity, incidence and AUDPC were recorded from combination of Liben variety and Natura (250 EW) fungicide application. But its yielding capacity was relatively low as compared with Natura (250EW) fungicide sprayed Kakaba variety. Thus combination of Kakaba variety and Natura (250EW) fungicide application is recommended for farmers as a best alternative for bread wheat production in the study area.

Acknowledgments

I would like to thanks Debre Markos Agricultural Research Center for providing improved seeds of different bread wheat varieties with their full information.

Abbreviations

AUDPC	Area Under Disease Progress Curve
CSA	Central Statistic Agency
CV	Coefficient of Variance
DAP	Date After Planting
GY	Grain Yield
PSI	Percentage of Severity Index

Conflicts of Interest

The author declared has no conflicts of interest.

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