**Evaluation of different fungicides against malt barley leaf scald and net form net blotch diseases in highlands of Sidama, Ethiopia**

ABSTRACT

*Barley is primarily regarded as a food crop in Ethiopia, ranking fifth after teff, maize, sorghum, and wheat. Ethiopia's barley production is low at 1.97 t/ha compared to the global average of 3.1 t/ha. Various biotic and abiotic stressors primarily contribute to the crop's declining productivity. Approximately 40 plant diseases affecting barley have been identified in Ethiopia. Among these, barley scald and net blotch foliar diseases are prevalent, reducing barley output globally, including in Ethiopia. A field experiment was conducted to assess the effectiveness of the Rescue 430SC fungicide against net blotch and leaf scald diseases in barley. The experiment's results indicated that fungicide-treated plots showed a significant difference compared to the control treatments across all variables. Evidence from the verification trial demonstrated that Rescue 430SC at a rate of 0.5 liters/ha mixed with 250 liters of water significantly managed barley net blotch and leaf scald at a 5% probability level, consequently increasing barley grain yield compared to the standard check (Natura 250 SC and Pajaro 420SC) and unsprayed checks in the tested locations. Based on the present investigation, it is concluded that Rescue 430SC was the most effective in minimizing barley net blotch and leaf scald across all experimental locations. During the growing periods, no foliar toxic effects were observed from any of the tested fungicides. Overall, results indicated that Rescue 430SC at a rate of 0.5 liters/ha with 250 liters of water was highly effective in controlling barley net blotch and leaf scald diseases. Therefore, it is recommended for registration to manage barley net blotch and leaf scald diseases.*

**Keywords**: Net blotch, Leaf scald, Severity, AUDPC, Rescue 430SL, Malt barley,

1. **INTRODUCTION**

Barley (*Hordeum vulgare* L.) is a self-pollinating crop with 2n = 2x = 14. Among the earliest crops to be domesticated, barley produced 160.23 million tons, coming in fourth place among cereals, after maize, rice, and wheat (FAO STAT, 2022). In terms of growing area, barley ranks fifth among Ethiopia's cereal crops, after tef, maize, sorghum, and wheat (Asfaw 2000). It is mostly grown as a food crop in a range of altitudes, 1500 to 3500 meters above sea level (Birhane et al. 1993). Barley is used as a staple meal for many humans across the world, particularly in low-income households, in addition to animal feed and malting (Newton *et al.* 2011). It is a nutrient-dense cereal crop with high protein content, numerous chemical components, and dietary fibers that reduce blood cholesterol and support intestinal function. Mostly, it is used for human nourishment as a traditional method in the malt industry (Poehlman, 1994). Barley flour was used for bread until the sixteenth century, when wheat was no longer used (Bukantis and Goodman, 1980). “Barley grain is used for the preparation of different foodstuffs in Ethiopia, such as malt production, injera, porridge, roasted grains, and different local drinks, and the straw and stem stubs are a good source of feed for animals and roof thatching, respectively, in Ethiopia” (Fenta,2018). “In Ethiopia, barley production increased in terms of area and grain yield from time to time, however, the level of yield under farmers’ conditions is lower than worldwide and national yield potential obtained under well-managed plots in the country” (Bekele *et al*. 2001). “Its productivity is low (1.97 t/ha) in as compared to world average of 3.1 t/ha, and the reduction in productivity of the crop is mainly attributed to multidimensional biotic and abiotic stresses” (Yitbarek *et al*. 1996). According to Yitbarek *et al*. (1996), “foliar diseases caused by various forms of fungi and viruses are a major constraint to barley production in Ethiopia, frequently causing crop losses and reducing grain quality”.

“Net blotch, scald, barley yellow dwarf virus and leaf rust are the most important barley diseases and most importantly targeted for control in the country” (Yitbarek *et al.* 1996; Bekele *et al.* 2001). “Both net form of net blotch caused by *Pyrenophora teres F. teres* (Ptt) and spot form of net blotch caused by *Pyrenophora teres F.maculata* (Ptm) are economically important foliar diseases throughout the major barley growing regions of the world, including Ethiopia” (Yitbarek et al. 1996; Liu et al. 2011). “Barley net blotch, which is caused by the fungal phytopathogen *P. teres* constitutes a serious constraint to barley production worldwide and losses caused by Ptt and Ptm are variable depending on environmental factors, stubble management practices, crop and cultivar rotations and timely application of fungicides” (Turkington et al. 2015). “Yield losses of 10% to 40% were reported as typical in severe cases of net form of net blotch” (Murray and Brennan 2010). “Similarly, yield losses of 4% to 44% were reported for the spot form of net blotch” (McLean et al. 2016).

“Pyrenophora teres is a haploid ascomycete that causes net blotch in barley, occurring in two forms: P. teres f. teres (PTT) and P. teres f. maculata (PTM). PTT disease, known as net form net blotch (NFNB), involves necrotic lesions along leaves with net-like striations. PTM infection results in spot form net blotch (SFNB), with discrete ovoid lesions”. (Syme et al.,2018). Leaf scald infection is characterized by water-soaked lesions on the leaf and sheath, which can be oval or irregular-shaped, grey-green, and change to straw with a dark brown edge. The infection can cause the leaf to wither and die, potentially spreading to all parts of the plant (McLean,2012). “In Ethiopia, net form of net blotch is an important disease in most parts of the highlands of the country where barley is widely cultivated” (Yitbarek et al. 1996). “It causes a substantial grain yield loss of 27% on average and up to 34% when it is severe” (Bekele et al. 2001). “Net blotch development also can lead to reductions in kernel weight, plumpness, and test weight, resulting in grade losses, a loss of malt status, or reduced acceptability as high-quality feed grain” (Yitbarek and Wudneh 1985). “In many parts of the world, fungicide applications, cultural practices and the use of resistant cultivars are the recommended disease management methods” (McLean et al. 2012)

“In Ethiopia, about 40 plant diseases have been recorded on barley. Among which net blotch and scald are the most important barley diseases causing significant yield and quality loss” (Yitbarek et al.1996). “Among them, widespread occurrences of barley scald and net blotch foliar diseases are limiting barley production worldwide, including Ethiopia” (Xi K et al.1996). “Furthermore, barley net blotch and scald diseases are widely distributed foliar diseases of barley, limiting its production in Ethiopia. The disease has been reported to cause high yield loss, reaching up to 34%” (Yitbarek et al.1996). “The combined yield loss from net blotch and scald in central highlands ranged from 14% to 25% in 1999 and 2000, respectively. In western Ethiopia, scald caused yield losses of 9.8% to 31.54%. The disease is an ever-endemic problem in most parts of Ethiopia's highlands, causing extensive grain yield loss, ranging from 27% on average to up to 34% when severe” (Yitbarek *et al*.1996). The occurrence of these diseases, along with poor quality and low-yielding varieties, is a major constraint for barley-producing zones of Ethiopia (PPSE,2008). “A mixture of inoculums can cause more yield reduction in barley than either pathogen alone, suggesting that the net blotch and scald pathogens may interact during infection and leaf disease development. The disease is most severe during seasons of above-average rainfall. Net blotch and leaf scald diseases require adequate moisture for spore germination, infection, and subsequent disease development. Scald can rapidly develop under cool and wet growing conditions. Net blotch develops more rapidly in warm, damp weather, but it can develop under cool conditions” (Tekauz 2003). “Net blotch and scald of barley can be managed by the use of resistant cultivars, fungicide foliar application, and seed treatment” (Martin 1985) and “cultural practices such as crop rotation and barley variety rotation using varieties with different genetic resistance” (Turkington *et al*. 2005). “Fungicides should be selected based on the local resistance prevalence, and compounds should be alternated based on their mode of action. Furthermore, the simple removal of plant straw and stubble treatment is well suited to reduce fungal inoculum. Farmers used different fungicides due to the barley disease's aggressiveness under field conditions to prevent yield loss due to these diseases. Research reports support the fact that unwise use of fungicides has led to the development of resistance to the pathogen” (Green 1990). Prospects for control of the disease are limited due to unavailability of suitable registered fungicides and a lack of resistant malting-quality cultivars. Effective management of barley diseases is crucial for controlling them during growth periods. To achieve this, there is a need for alternative and effective fungicides, such as new fungicides or different formulations of existing ones. Regular testing and verification of the efficacy of new fungicides on net blotch and leaf scald of barley is necessary. The efficacy of fungicides is influenced by environmental factors, disease occurrence, application time, and rates of application. To maximize a greater number of fungicide options in the market and to identify effective fungicides, frequent verification and evaluation of new fungicides against barley net blotch and leaf scald is important to sustain barley production and productivity.

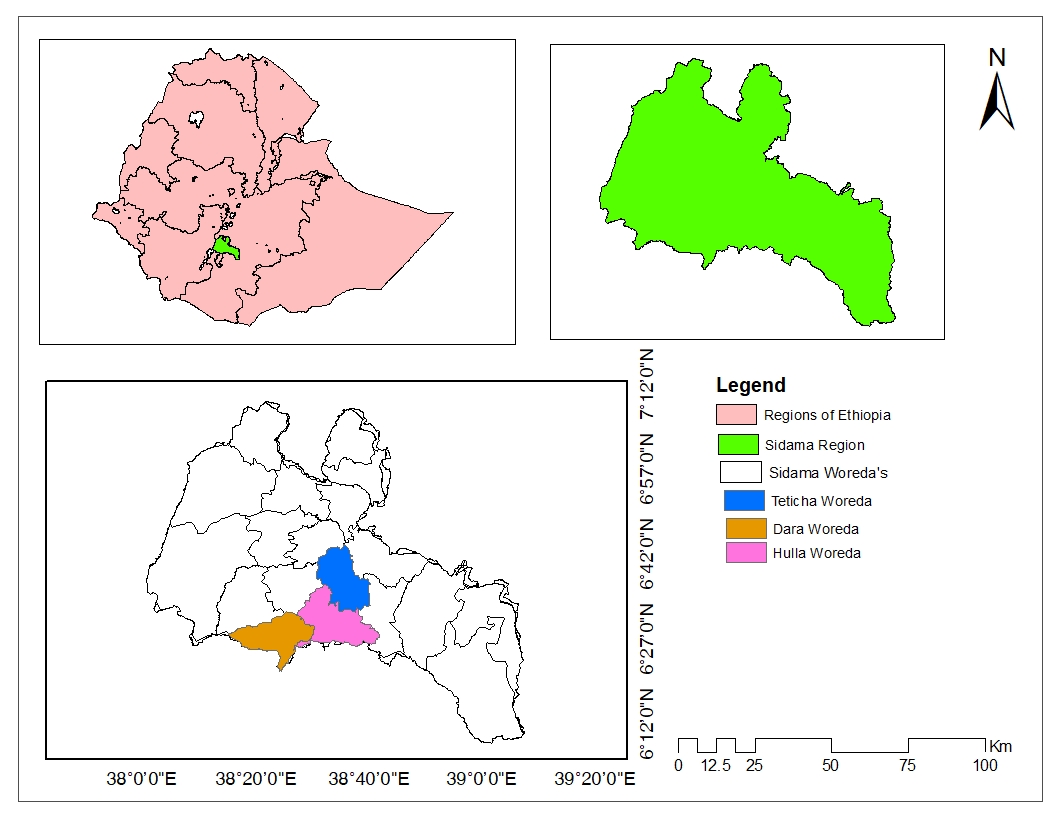
The Ethiopian Agriculture Authority has assigned the Hawassa agricultural research center to test the new fungicide, Rescue 430SC, against net blotch and leaf scald of barley during the 2024 cropping season. The study aims to evaluate the efficacy of Rescue 430SC in comparison to other promising standard fungicides, Natura 250 SC and Pajaro 420 SC.

1. **MATERIAL AND METHODS**
   1. **Descriptions of the study site**

The experiment was conducted at three locations: Dara Otilcho (Abera Gelede sub-station), Hula (Ganjure Chicho Farmers Training Center/FTC/), and Teticha district (Teticha 02 FTC) during the 2024/2025 main cropping season. The districts are among the major malt barley-growing areas of the Sidama Region and were selected based on the production potential of malt barley and a hot spot for the development of malt barley leaf scald and net form net blotch disease epidemics. The three experimental sites are geographically located at 06O 29’ 59’’ N and 038o 24’59’’ E (Abera Gelede substation), 06O 27’45’’ N and 038O 34’45” E (Ganjure Chicho FTC), and 06O 55’76’’ N and 038O 52’ 36’’ E (Teticha 02 FTC). The sites are found at an elevation of 2697 (Abera gelede), 2752 (Ganjure Chicho FTC), and 2681 (Teticha 02 FTC) meters above sea level.

Abera Gelede station is located around 100km from Hawassa, a regional city, and 375km from the capital city of Addis Ababa, Ethiopia. The geographical position of the district, where Abera Gelede station is located in Dara Otilcho district, geographically finds 38°38’–38°51’ E and 6°36’–6°54’ N, and the altitude ranges from 1200-2900 meters above sea level (masl) and specifically the experimental site is elevated 2752masl. The annual temperatures of the district range from 19°C and 28°C. The area is characterized by three traditional classified seasons; long rainy seasons extending from May to June; short rainy seasons ranging from September to November; and dry seasons extending from December to April.

Teticha 02 FTC is located in Teticha district recently separated from Hula district. Teticha district has a “dega” or cool zone climate and is 361 km from Addis Ababa, the country’s capital, and 88km from Hawassa, the regional capital. Gajure Chicho FTC is located in the Hula district. The district has an elevation ranging from 2100-3200 meters above sea level and a temperature range of 10-180C. The district's longitudinal and latitudinal coordinates are 38° 46'–38° 78' E and 6° 40'–6° 75' N, with a mean altitude of 2809masl. The rainfall pattern of the area is bimodal and receives ranges from 1100-1400 mm per annum, allowing two cropping seasons in a year. The long rainy season begins in July and ends in September and the short rainy season ranges from March to May.The district's mean minimum and maximum temperatures were 6.2 °C and 19.1 °C, respectively, with an average annual rainfall of 1425 mm.



**Figure 1**. Map of study areas.

* 1. **Treatments, Design of Experiment, and Management Procedures**

Maly barley cultivar (planet), highly susceptible to net blotch and leaf scald disease, was planted in nonreplicated plots of 5m x 5m size, where locations were considered a replica. The plots were spaced 2 m apart and 1.5 m between plots. The seed and fertilizer rates of 150 kg ha-1 and 41/46 N/P2O5kgha-1 were used, respectively. Test fungicide, RESCUE 4300 G/L EC (Tebuconazole 4300g/l SL) provided by WANDANY TRADING PLC. Currently, the widely used fungicides Natura 250 EW and Pajaro plus 420 SC (Prothioconazole 210 + Tebuconazole 210) are included as a standard check along with an untreated check (control). Land preparation and weeding were done manually as recommended for barley. The test fungicide was applied manually using a knapsack sprayer with a rate of 1 lit/ha, diluted in 250 lit/ha water, and sprayed at a 5% severity level of net blotch and leaf scald disease.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Trade name | Common name | Active Ingredient (a.i) | Registration Number | Shelf lives  (years) | Mode of action | Application stage | Rate of application | |
| Herbicide  Lha-1 | Herbicide  Lha-1 |
| Rescue 430 SC | Tebuconazole | Tebuconazole 430g/l SC | New | 2 | Systemic | At crop tillering | 0.5 | 250 |
| Pajaro Plus 420 SC | Prothioconazole  **+** Tebuconazole | Prothioconazole 210gm/l  **+** Tebuconazole 210gm/l | ET/FN/R31/2021 | 2 | Systemic | 0.3 | 175 |
| Natura 250 EW | Tebuconazole | Tebuconazole 250G/L | ET/FN/R125/2013 | 3 | Systemic | 0.65 | 250 |
| Untreated | - | - | - | - |  | - | - | - |

**Table 1.** Fungicide trade name, common name, content of active ingredients, registration number, shelf live, mode of action, and application rates

**Source**: Data were sourced and organized from the Ministry of Agriculture (MoA, [2015](https://www.tandfonline.com/doi/full/10.1080/23311932.2020.1739493)) and the product package booklet

* 1. **Net Blotch and Scald Diseases Assessment**

Disease severity for scald and net blotch disease was scored on ten randomly chosen plants in each plot using modified Saari and Prescott’s double-digit scale (D1D2, 00-99) scoring method (Saari and Prescott, 1975). which was based on the severity scale to assess foliar diseases in cereals. The first digit (D1) indicates the relative height of the disease on the plant and corresponds to the vertical disease progression using the original 0-9 Saari-Prescott scale. While the second digit (D2) refers to severity measured as diseased leaf area. In each location, the diseases scoring was repeated five visually scored for each plot not treated with fungicide between growth stages Z69 and Z83 (Zadoks *et al.,* 1974; Tottman and Hilary, 1987) using the double-digit scale (00-99) developed as a modification of Saari and Prescott’s severity scale to assess barley foliar diseases (Saari and Prescott, 1975; Eyal *et al.,* 1987). For each score, disease severity percentage was based on the following formula: Percentage Disease Severity (PDS%) = (*D*1/9) X(*D*2/9) X100. Area under disease pressure curve (AUDPC) was calculated to estimate the scald severity over time based on the five growth stages' percent disease severity estimation according to (Das *et al.*,1992; Shaner and Finney,1977) formula:



where *x i* = scald & spot blotch severity on the *i*th date, *ti = i*th day, and *n* = number of dates on which scald & spot blotch was recorded. The AUDPC gives a quantitative measure of epidemic development and disease intensity (Reynolds and Neher, 1997). Data on yield and yield components were recorded based on crops harvested from a net harvestable plot area of 25 m2 and converted to a hectare base. Crop stand count per m2 was taken by counting five middle rows randomly selected in each plot. Plant height was measured from 10 plants randomly selected in each plot, and their average was calculated. The number of productive tillers was counted from five rows with a length of 1m randomly taken in each net plot area and was converted into m2 at harvest. The number of grains per spike was determined from randomly taken 10 spikes per plot. The spike length was measured from 10 randomly selected plants in each plot. Thousand grains weight was counted from the bulk of threshed produce from the net plot area, and their weight was recorded. Grain yield (kg ha⁻¹) was measured after threshing the sun-dried plants harvested from each net plot, and the yield was adjusted at 12.5% grain moisture content (Amare *et al*., 2014). The biological yield was determined by taking the total weight of the harvest from each net plot area after sun-drying the whole aboveground biomass. The harvest index and yield loss were also calculated. The harvest index was calculated by the formula:

Relative yield loss (%): Potential reduction of grain yield loss (in the absence of foliar spray of fungicides) was calculated as yield difference between fungicides sprayed and control treatment expressed in percentage of the sprayed plots, in other word, yield increase over the change of yield increase to untreated plots (Sharma *et al*.,2016) as follows;

The fungicide efficacy (FE) was calculated as stated

* 1. **Data Analysis**

Data on terminal severity of leaf scald and net blotch at the final assessment date, and respective AUDPC values, were subjected to analysis of variance to determine the treatment effects. Analysis of Variance (ANOVA) was done by using General Linear Model Procedure SAS Version 9.3(SAS, 2009), and means comparisons for the significantly different variables were made among treatments using Least Significant Differences (LSD) test at P< 0.05 level of significance (Gomez and Gomez, 1984).

1. **RESULTS AND DISCUSSION**
   1. **Disease Epidemics**

In the 2024/25 main cropping season, both net form of net botch and leaf scald disease pressure were very high, and excellent disease epidemics were developed to the level of creating significant differences among treatments across all test locations in Sidama Highlands. Fungicide spray treatments (test and check fungicides) significantly reduced both the net form of net botch and leaf scald disease severity over the untreated(nil) application. However, there was no statistically significant difference between the test and check fungicides and among the test fungicides in reducing both the net form of net botch and leaf scald disease severity, except there were significant differences with the standard check Pajaro 420SC (Table 2). Even though there was no statistically significant difference between the test and check fungicides, Natura 250SC (standard check fungicide) reduced both net form of net botch and leaf scald disease severity to the lowest level compared to the test fungicides, Rescue 430 SC. However, from visual field observation, the test fungicide, Rescue 430SC, showed a comparable level of efficacy in controlling both the net form of net botch and leaf scald diseases with the standard check, Rescue 430SC, Natura 250SC reduced net form of net botch and leaf scald diseases severity by about (36.7 %, 31.7 %) and (39.7%, 33.3%) respectively as compared to unsprayed plot. Whereas Pajaro 420 SC reduced the net form of net botch and leaf scald disease severity by about 53.0 and 42.0 %, respectively. The maximum recording of net form of net botch and leaf scald (88.3%, 71.7%) was obtained on the untreated plot across the study area in order (Table 2). This work was similar to the previous research reports of (Lera, 2023; Beyene and Abera,2019**)** done on the evaluation of fungicides' efficacy against net blotch and leaf scald of barley in Ethiopia.

Across experimental locations, the highest AUDPC for net blotch and lower grain yield was noted from the unsprayed control plots. Conversely, AUDPC and the highest grain yield were noticed from the Rescue 430 SC sprayed plots, which showed no significant difference with Natura 250SC, but a significant difference in sprayed plots of Pajaro 420SC (Table 1). Rescue430 SC sprayed plots reduced leaf scald and net blotch AUDPC and increased the grain yield of malt barley when compared with other treatments. Across test sites, the lowest AUDPC recorded was on plots sprayed with Rescue 430 SC (1138.7 days unit) and 1213.3 days unit of Natura 250 SC and on leaf scald while the highest AUDPC was recorded from the unsprayed control plot: 2583.0 days unit and 2496.7 days unit for net form net blotch and leaf scald diseases, respectively (Table 2). Generally, the significant difference in AUDPC among the evaluated fungicides might be due to the characteristic nature of the product formulations. The result of this study was similar to Lera (2023) recent research finding on the effects of Aleka 33% EC fungicide and Beyene and Abera's (2019) research conducted at West Showa Zone, Ethiopia, on different fungicide verification trials.

**Table 2**. Mean Effect of Severity Index Percentage (SI%) and Area Under Disease Progress Curve (AUDPC) of Leaf scald and net form net blotch of Malt barley at Sidama highland in 2024/2025 main cropping season

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | Leaf Scald | | Net form net blotch | |
|  | SI% | AUPC | SI% | AUDPC |
| Rescue 430SC | 31.7c | 1138.7c | 36.7c | 1334.7c |
| Natura 250SC | 33.3c | 1213.3bc | 39.7c | 1519.0bc |
| Pajaro 420SC | 42.0b | 1381.3ab | 53.0b | 1887.7b |
| Untreated (Nil) | 71.7a | 2496.7a | 88.3a | 2583.0c |
| Mean | **44.7** | **1560.0** | **54.43** | **1831.1** |
| LSD α=0.05 | 7.6 | 210.8 | 6.15 | 389.47 |
| CV% | 8.47 | 6.75 | 5.66 | 10.65 |

*SI% %: severity index percentage; AUDPC: area under progress curve; LSD: list significant difference; and CV: coefficient variation.*

* 1. **Effect of Fungicides on Grain Yield and Yield Component** 
     1. **Plant Height**

The statistical analysis showed that there was a significant effect observed among fungicide treatments and untreated plots on plant height across study areas of Sidama highland woredas during the 2024/2025 crop growing season. (Tables 3). This study was similar to (Lera,2023; Beyene and Abera, 2020; Tamene and Zerihun,2020) research report from the Bale zone, plant height was not statistically significant; rather plant it is genetically determined.

* + 1. **Tiller numbers**

The statistical analysis showed that there was a significant effect observed among fungicide treatments and untreated plots on plant height across study areas of Sidama highland woredas during the 2024/2025 crop growing season. (Tables 3). Productive tiller numbers were significantly different between the treatment and the control(nil) plot. The maximum tiller number (9.8) was observed on Rescue 430 SC and followed (9.7) by Natura 250SC, while the minimum productive tiller number (8.3) was recorded on the Untreated plot, statistically significant, not only impacted by genetic and soil nutrients determinants. This study was similar to (Lera,2023; Beyene and Abera, 2020; Tamene and Zerihun,2020) research reports from different Ethiopian regions

* + 1. **Spike Length (cm)**

Statistical analysis revealed a significant (P < 0.05) effect of the treatment combination on spike length of study areas (Tables 3). The greatest spike length of 8.8 cm was obtained from the plot treated with Rescue 430 SC, followed by the plot sprayed with Natura250 SC fungicide (8.3cm). On the other hand, the shortest spike lengths of 7.4cm were obtained from the untreated plots (Tables 3). Spike length is considered an important yield-contributing trait. The reductions in spike length due to barley leaf scald and net form net blotch contributed to the lowest grain yield. However, significant increases in spike length were obtained due to the application of fungicide. Analysis of the statistics result showed that the spike length of the protected plots was greater than that of the infected/unprotected plots during the study season. The application of fungicides suppresses disease development and protects the crop canopy, which is vital for dry matter accumulation and yield. Likewise, (Lera,2023; Beyene and Abera, 2020; Tamene and Zerihun,2020) a recent report finds that spike length significantly affects fungicide application and contributes to grain yield and quality.

* + 1. **Kernel Per Spike**

The current study revealed that fungicide application frequency and combination had a significant (P 0.05) effect on the number of kernels per spike (Tables 3). The highest numbers of kernels per spike, 25.5 with Test fungicide Natura 250 SL, followed by 25.4 with test fungicide Rescue 430SC fungicide treated, while the lowest numbers of kernels per spike, 20.0, were obtained from the untreated plot. No significant difference was observed among fungicides, but there was a significant difference between the control or untreated plot compared with treated plot by fungicides. The number of kernels per spike is one of the most important yield parameters (Lera, 2023; Tamene and Zerihun,2020). Leaf scald and net blotch attack the glumes and awns of barley, accumulating spores on the florets and the surface of the developing grain. These situations contributed to the minimum number of kernels of the variety tested. A reduction in grain number and size reduces the dry matter content of malt barley grains by affecting the sugar supply to developing seeds, which directly results in a large yield loss (Lera, 2023; Beyene and Abera, 2020). However, healthy and robust grains resulting from the application of foliar fungicides contribute to overall grain yield. Fungicide applications protect the flag leaf from infection until after the kernels have filled. The application of fungicide as per the manufacturer's recommendation at the proper time and rate increased the number of kernels per spike by reducing the disease pressure to the lowest level.

**Table 3.** Effects of fungicides on Plant height, spike length, number of seeds per spike, and kernel number per spikelet of Malt Barley at Sidama Highland in 2024/2025 Main Cropping Season

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | Plant height (cm) | Spike length (cm) | Tiller number | Kernel numbers per spike |
| Rescue 430SC | 66.9a | 8.8a | 9.8a | 25.4a |
| Natura 250SC | 65.9a | 8.3ab | 9.7ab | 25.5a |
| Pajaro 420SC | 65.8a | 8.0a | 8.6ab | 24.1a |
| Untreated (Nil) | 64.6a | 7.4b | 8.3b | 20.0b |
| Mean | **65.8** | **8.13** | **9.1** | **23.8** |
| LSD α=0.05 | Ns | 1.14 | 1.46 | 3.61 |
| CV% | 2.22 | 7.04 | 8.02 | 7.51 |

*LSD: list significant differences and CV: coefficient of variation*

* + 1. **Thousand** **Kernel Weight (g)**

The statistical analysis revealed that there was a nonsignificant effect observed among the fungicide treatments and the untreated plot on 1000-kernel weight along the study areas (Tables 4). However, there was a significant effect observed among the fungicide treatments and the untreated plot on 1000-kernel weight, there was a non-significant effect observed among the fungicide. However, there was a significant effect observed among the fungicide treatments compared to the untreated plot on 1000-kernel weight. The result revealed that rescue 430S and Natura 250 SC fungicide applications significantly increased 1000-kernel weight compared to the untreated plot (Table 4). The test fungicides significantly increased thousand kernel weight compared to the control, but did not significantly differ from the standard check Natura 250SC, except for Pajaro 420SC statistically significant. These current findings are in agreement with the work by Lera (2023) that a highly significant effect was observed among test fungicides and nil application for the increment of thousand kernel weights. The highest thousand kernel weight was obtained from Rescue 430SC (46.8g), followed by Natura 250 SC (42.1g) and Pajaro 420 SC (40.4g) applications, whereas the lowest was obtained from the untreated plot (39.3g) application (Table 4). The Pajaro 420 SC applied plot and the control(nil) plot were not statistically different. Though fungicide application significantly increased the amount of thousand-kernel weight. Similarly, it was previously reported that the fungicide treatments had a strong impact on the control of infection of increased kernel yield in variable disease infection conditions (Tamene and Zerihun,2020).

* + 1. **Grain yield (t/ha)**

Analysis of variance revealed a significant (P < 0.05) effect of fungicide application frequency on grain yield across study areas (Table 4). The maximum grain yield of 2.9 t/ha was obtained from the treatment with the new Rescue 430 SC test fungicide, followed by the Pajaro 420 SC fungicide (2.3 t/ha). The lowest grain yield of 1.8 t/ha was observed in the untreated plots. Grain yield differences and losses were most pronounced across the experimental site due to severe disease pressure. Similarly, Lera (2023) and Tamene and Zerihun (2020) suggested that variability in yield depends on the extent of disease pressure. A contrary relationship was found between disease severity and grain yield, implying that leaf scald and net form net blotch diseases directly affect kernel quality, causing barley grains to shrink. The newly tested fungicides and both standard checks outperformed the untreated control concerning grain yield. The use of Rescue 430 SC reduced disease severity while increasing grain yield. Several previous studies across different regions have confirmed yield increases in barley attributed to fungicide application (Mark *et al.,*2019), which revealed that applying foliar fungicides to barley prevented up to 23% yield loss. Likewise, Lera (2023) reported that fungicide-treated plots remained almost free of Leaf scald and net blotch leaf diseases of barley. Nevertheless, the fungicides Rescue 430 SC and Natura 250 SC do not show significant differences in effectiveness, while Pajaro 420 SC differs significantly. The tested and standard check fungicides provided better control of leaf scald and net blotch of leaf diseases of barley compared to no application. In general, the current study clearly shows that in Ethiopia, growing susceptible to moderately susceptible malt barley varieties without fungicide application were not feasible in areas where leaf diseases of barley are a major concern, especially in the highland malt and food barley-growing regions of the Sidama highlands of Ethiopia.

* + 1. **Biological and straw or biomass yield(t/ha)**

A significant effect (P<0.05) was observed among the fungicide treatments and the untreated plot regarding grain biomass and straw yield across the locations (Table 4). The maximum biological and straw or biomass yield (7.5t/ha and 4.4t/ha) occurred with fungicide Rescue 430SC treatments, followed by Natura 250SC (6.5 t/ha and 3.2t/ha) for biological and biomass yield, respectively. The untreated plot yielded 5.2 t/ha and 2.1t/ha for biomass and straw yield, respectively. However, there was a significant effect observed among the fungicide treatments and the untreated plot for biological and biomass yield in tons per hectare (Table 4). The current finding is similar to the report of Tamene and Zerihun (2020), the research done on blotch and leaf rust in the Bale zone of Ethiopia.

* + 1. **Harvest index**

The application of different herbicides showed no significant difference(P<0.05) compared to the untreated (nil)plot in harvest index (Table 4). The application of all fungicides showed statistically no significant differences. The maximum number of harvest indexes (43.7%) at Rescue 430 SL might be related to higher total biomass production, while the minimum Harvest index (40.3%) was recorded on the Untreated plot. The result also clearly indicated that the harvest index was lower at higher total biomass production. Similar findings were reported by Amare *et al*. (2014) concluded that the harvest index increased with a decrease in disease infection.

* + 1. **Yield loss**

The different fungicide applications were highly significant in the yield loss of barley at P<0.05 comparison level. The use of Rescue 430 SL gave the lowest yield loss (16.2%) as compared to other tested fungicides, but a maximum yield loss of 49.5% was obtained from the untreated plot (Table 4). The application of all fungicides revealed statistically no significant differences among them, there were significant differences compared to the nil or untreated plot. The lowest yield loss at Rescue430 SL could be related to higher barley leaf scald and net blotch reduction or control, more yield components, and better crop growing conditions to produce higher yields. In contrast, higher barley leaf scald and net blotch severity percentage resulted in the greatest yield reduction due to infecting barley at the growing stage and affecting the grain kernel weight and quality in the plots. The highest yield loss was obtained from control or nil plots as a result of higher disease severity and rate of progress. The finding conformed with the work of Amare *et al.* (2014) reported that the highest yield loss was at the control. On the other hand, yield reduction is high in barley due to numerous barley diseases, including leaf scald and net form net blotch throughout the crop-growing season.

**Table 4**. Mean Effect of Rescue 430SC on Grain Yield, Biological Yield, Biomass Yield, Harvest Index, and Yield Loss of Malt Barley at Sidama Highland in 2024/2025 Main Cropping Season

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatments | Grain yield, Yield components, and Yield loss of malt barley | | | | | |
|  | TKW (gm) | BWY (t ha-1) | BMWY (t ha-1) | GY (t ha-1) | Harvest index (%) | Yield loss (%) |
| Rescue 430SC | 46.8a | 7.5a | 4.4a | 2.9a | 43.7a | 16.2b |
| Natura 250SC | 42.1ab | 6.5ab | 3.2b | 2.2b | 42.8a | 33.3ab |
| Pajaro 420SC | 40.4b | 6.1ab | 3.1b | 2.3b | 40.8a | 36.2ab |
| Untreated (Nil) | 39.3b | 5.2b | 2.1b | 1.8b | 40.3a | 49.5a |
| Mean | **42.2** | **6.3** | **3.2** | **2.3** | **41.9** | **33.8** |
| LSD α=0.05 | 5.36 | 1.45 | 1.16 | 0.66 | Ns | 18.92 |
| CV% | 6.36 | 11.53 | 17.97 | 14.49 | 14.20 | 28.01 |

*TKW: thousand kernel weight; BYW: biological yield; BMY: biomass yield; GY: grain yield; t ha-1: tone per hectare, LSD: list significant difference at P< 0.05, and CV: coefficient variation*

1. **SUMMARY AND CONCLUSION**

Barley net blotch and leaf scald cause serious problems in the study areas during the production season. The experiment result showed that fungicide-treated plots showed a significant difference compared to the control treatments in all variables. Evidence obtained from the verification trial showed that Rescue 430SC at the rate of 0.5 lit/ha with 250 liters of water acted significantly at a 5% probability level in managing barley net blotch and consequently increased grain yield of barley as compared to the standard check (Natura 250 SC), Pajaro 420SC, and unsprayed checks across tested locations.

Considering the present investigation, it is concluded that Rescue 430SC was found to be the best by minimizing barley net blotch and leaf scald in all experimental locations. During the growing periods, no foliar toxic effect was observed from the effect of any tested fungicides. Generally, results showed that Rescue 430SC, at the manufacturer's recommendation, was highly effective in controlling barley net blotch and leaf scald diseases of the barley. Therefore, rescue 430SC was found highly effective for the barley net blotch and leaf scald diseases on barley, and therefore it is recommended for registration for the management of the barley net blotch and leaf scald diseases of the barley.

**ACKNOWLEDGMENT**

The authors are grateful to the Sidama Region Agricultural Research Institute (SIRARI) and Hawassa Agricultural Research Center (HARC) for vehicle and logistical support during the experiment and Wandany Trading PLC for covering the costs related to the field experiment, though there is no financial support at all for publishing the article

**DISCLAIMER (ARTIFICIAL INTELLIGENCE) Author(s)**

Hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**COMPETING INTERESTS**

Authors have declared that no competing interests exis

**REFERENCES**

Asfaw, Z., (2000). The Barleys of Ethiopia. In: Stephen BB (eds) GENES in the FIELD: On-farm Conservation of Crop Diversity. International Development Research Centre and International Plant Genetic Resources Institute. *Lewis Publishers is an imprint of CRC Press LLC,* Rome, pp. 77-108.

Bekele, H., Shambel, K. and Abashamo, L., (2001). Barley yield loss due to net blotch and leaf rust in Bale Highlands. *Pest Management Journal Ethiopia.* 5: 45-53.

Berhane, L., Hailu, B. and Fekadu A., (1993). Barley production and research. In: Hailu-Gebre, Van Leur JAG (eds) Barley Research in Ethiopia: Past Work and Future Prospects. *Proceedings of the 1st Barley Research Review Workshop*. Addis Ababa, Ethiopia, pp. 1-8.

Beyene, N. and Abera, A., (2020). Evaluation of Different Fungicides for the Control of Net Blotch (*Pyrenophora teres*) Disease on Barley (*Hordeum vulgare* L.) at West Showa Zone, Ethiopia. *Journal of Plant Pathology and Microbiology.* 11: 487

Beyene, N., Abera, A., (2020). Evaluation of Different Fungicides for the Control of Net Blotch (*Pyrenophora teres*) Disease on Barley (*Hordeum vulgare* L.) at West Showa Zone, Ethiopia. *Journal of Plant Pathology Microbiology.* 11: 487.

Das, M.K., Rajaram, S., Mundt, C.C. and Kronstad, W.E., (1992). Inheritance of slow rusting resistance to leaf rust in wheat. *Crop Science.* 32:1452-1456.

Eyal, Z., Scharen,A.L., Prescott, J.M. and van Ginkel,M., (1987). The Septoria disease of wheat: Concepts and methods of disease management. CIMMYT, Mexico

FAO STAT. (2022) Crops/Regions/World List/Production Quantity for Barley. *Food and Agriculture Organization Corporate Statistical Database* (FAOSTAT).

Fenta ,A., (2018). Effect of fertilizer on the growth response of food barley (Hordeum vulgare L.). *Journal of Agriculture.* 13: 40-47.

Green, M. B., LeBaron, H. M. and Moberg, W. K.,1990. Managing resistance to agrochemicals*. From fundamental research to practical strategies.*

Lera, Z.T., (2023). Evaluation of Aleka 33% EC Fungicide against Net Blotch (*Pyrenophora teres*) and Leaf Scald Diseases (*Rhynchosporium secalis*) on Barley. *J Plant Pathol Microbiol.* 14:705

Liu, Z., Ellwood, S.R., Oliver, R.P. and Friesen, T.L., (2011). Pyrenophora teres: Profile of an increasingly damaging barley pathogen. *Molecular Plant Pathology.* 12: 1-19.

Mark, S., Mclean M.S. and Hollaway, G.J., (2019). Control of net form of net blotch in barley from seed and foliar applied fungicides. *Crop & Pasture Science.* 70: 55-60.

Martin, R.A., (1985). Disease progression and yield loss in barley associated with net blotch, as influenced by fungicide seed treatment. *Canadian Journal of Plant Pathol*ogy. 7: 83-90.

McLean,M.S., Weppler, R., Howlett, B.J. and Hollaway, G.J. (2016). Spot form of net blotch suppression and yield of barley in response to fungicide application in the Wimmera region of Victoria, Australia. *Australas Plant Pathology.* 45(1): 37-43.

McLean, M. (2012).Scald of barley. Agriculture Victoria, <http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/scald-of-barley>.

Murray, GM. and Brennan JP., (2010). Estimating disease losses to the Australian barley industry. *Australas Plant Pathology.* 39: 85-96.

Newton, AC., Johnson, SN. and Gregory, PJ., (2011). Implications of climate change on diseases, crop yields, and food security. *Euphytica.* 179: 3-18.

Poehlman, JM., (1994). National Center for Biotechnology Information (USA). [Corporate Author].

PPSE. (2008) *Plant Protection Society of Ethiopia.*

Reynolds, K.L., and Neher, D.A., (1997). Statistical comparison of epidemics. p. 34–47. *In* L.J. Francl and D.A. Neher (ed..) Exercises in plant disease epidemiology. APS Press, St. Paul, MN.

Saari, E.E. and Prescott, J.M. (1975). A scale for appraising the foliar intensity of wheat diseases. *Plant Disease Report*, 59: 377-380.

Shaner, G., Finney, R.E., (1977). The Effect of nitrogen fertilization on the expression of slow-mildewing resistance in knox wheat. *Phytopathology* 67: 1051-1056.

Syme, R.A, Martin, A, Wyatt, N.A,Lawrence, J.A, Muria-Gonzalez ,M.J,Friesen, T.L and Ellwood, S.R., (2018). Transposable Element GenomicFissuring in Pyrenophora teres IsAssociated With Genome Expansionand Dynamics of Host–PathogenGenetic *Interactions.Front. Genet*. 9:130.

Tamene, M. and Zerihun, E., (2020). Evaluation of Different Fungicides Efficacy Against Net Blotch (*Pyrenophorateres*) and Leaf Rust (*Pucciniahordei)* Diseases of Barley, South-Eastern Ethiopia. *European Journal of Biophysics*. 8(2):35-42

Tekauz A., (2003). Diseases of barley. In: Diseases of Field Crops in Canada. 3rd ed. K. L. Bailey, B. D. Gossen, R. K. Gugel, and R. A. A. Morrall (eds). Canadian Phyto pathological Society and University Extension Press, University of Saskatchewan, Saskatoon, Saskatchewan, *Canada.* 30-53.

Tottman, D.R., and Hilary,B., (1987). The decimal code for growth stages of cereals with illustrations. *Annexed Applied Biology*. 110:44- 454.

Turkington,TK., Tewari, Xi K., Lee, HK., Clayton, GW. and Harker, KN., (2005) Cultivar rotation as a strategy to reduce leaf diseases under barley monoculture. *Canadian Journal of Plant Pathol*ogy.27: 283-290.

Xi K, Bos C, Turkington., TK, Xue, AG., Burnett, PA. and Juskiw, PE., (1996). Interaction of net blotch and scald on barley. *Canadian Journal of Plant Pathology.* 30(2): 329-334.

Yitbarek, S., Bekele H, Dereje T. (1996). Disease survey and loss assessment studies on barley. In: Hailu G, van Leur J (eds) Barley Research in Ethiopia: *Past Work and Future Prospects, IAR/ICARDA,* Addis Ababa, pp. 105-115.

Yitbarek, S,.and Wudneh, E., (1985). Preliminary studies on yield losses due to net blotch in barley. In: Taddesse A (ed) *Proceedings of the 10th EPC Annual Meetings*, Addis Ababa, Ethiopia, pp. 47–52.

Zadoks, J.C., Chang, T.T. and Konzak, C.F., (1974). A decimal code for the growth stages of cereals. *Weed Research*. 14:415-421.