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RESEARCH PAPER

# Effect of mineral fertilizer applications in bread wheat varieties to yellow rust disease

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**Abstract**

This research was carried out to determine the effects of mineral fertilizer applications applied in different doses on disease severity according to phenological periods in some bread wheat varieties. In this study, bread wheat varieties (Bayraktar 2000, Demir 2000, Eser and Kenanbey) were used as plant materials. In the study, different doses of Fe ($Fe_5$, $Fe_{10}$, $Fe_{20}$) and Zn ($Zn_{7.5}$, $Zn_{15}$, $Zn_{30}$) and their combination Fe+Zn (Fe+Zn $_{(5+7.5)}$, Fe+Zn $_{(10+15)}$), in the period from tillering to stalking were investigated. When compared to the variety without fertilizer application in general, Eser, one of the bread varieties, caused a decrease in disease severity in all Fe dose applications, while Zn applications caused an increase in the early period and both an increase and a decrease in the late periods. Bayraktar variety caused an increase in disease severity in all Fe dose applications in all phenological periods and in all zinc applications except the $Zn_{7.5}$ dose. In the Kenanbey cultivar, Fe dose applications caused an increase in disease severity in all periods except the mid-late period, and zinc applications caused a decrease in disease in all periods except the early period. Variable increases and decreases were observed in all phenological periods in Demir 2000 variety. In the future, the effects of Fe and Zn, as well as other plant nutrients, will be studied. Disease development for local varieties can be revealed for different phenological periods and their accuracy can be increased.

## Introduction

Rust diseases are the most common wheat diseases in the world, causing significant yield and quality losses in wheat-growing ecologies (Samborski, 1985; Roelfs, 1978; Ipek et al., 2023; Tekin et al., 2022) and they can spread over large areas with prevailing winds. Additionally, their capacity to form new strains (race/pathotypes) in the biological process of the disease poses a potential threat to wheat production at the global level (Saari and Prescott, 1985; Kolmer, 2005; Cat et al., 2017; Cat et al., 2021; Tekin et al., 2021).

In recent years, detecting and controlling diseases in the early period has become very important due to the excessive use of fungicides and their harmful effects on the environment and human health. Sustainable agriculture and food safety have become increasingly important for both our country and the world in recent years. Although the physiological functions of plant nutrients are generally well understood, the dynamic interactions between plant nutrients and plant pathogen systems are poorly understood (Huber, 1996a). It has been reported, because of numerous studies, that fertilizer applications in the right amount and at the right time are important for higher unit area yield and for controlling some diseases (Marschner, 1995; Huber and Graham, 1999b; Graham and Webb, 1991). In recent years, nitrogen (N), phosphorus (P), potassium (K), manganese (Mn), zinc (Zn), boron (B), chlorine (Cl), and silicon (Si) have been used as plant nutrients in sustainable agriculture. These elements can be used to increase a plant's tolerance to disease or to reduce the severity of the disease. In general, plant nutrients can reduce plant diseases to an acceptable level (Dordas, 2008). While high N levels increase the severity of the disease in some cases where obligate pathogens are intense, it can be effective in reducing the severity of the disease in environments where facultative parasites are intense (Robert, et al., 2005). Potassium can reduce the development of host plants to their optimal growth level, while, unlike P and K, it can increase tolerance to diseases. Micronutrients play an important role in plant metabolism by affecting phenol, lignin content, and membrane stability (Graham and Webb, 1991). In addition, micronutrients have a variable effect on diseases, reducing the severity of the disease in some cases and increasing the severity of the disease in some cases (Huber and Graham, 1999b; Marschner, 1995; Römheld and Marschner, 1991). According to Graham and Webb (1991), the use of micro plant nutrients such as Mn and Zn instead of the recommended fungicide applications for the control and reduction of rust diseases during plant development can provide effective and lower-cost solutions as an alternative to fungicide applications without causing environmental pollution. The effects of micronutrients in reducing the severity of the disease seen in the plant are based on the healthy effect on the biochemistry and physiology of the plant. It has been reported that a significant portion of micronutrients has different and important responsibilities in the manifestation of resistant or tolerant reactions of plants against pathogens (Marschner, 1995). Micronutrients play a critical role in plant metabolism, influencing phenol and lignin content as well as membrane stability (Graham and Webb, 1991). Iron (Fe) is an important nutrient for human, animal, and plant health. However, research on the effect of Fe applications on strength to plant diseases is limited. Higher plants need higher amounts of Iron (Fe) for high productivity. Many foliar diseases, such as rust diseases in wheat and bananas, can be mitigated or controlled to varying degrees by iron (Graham and Webb, 1991). Iron applications increase tolerance to Sphaeropsis malorum in apples and pears and in pumpkins to Olpidium brassicae. In addition, additional fertilizer application in zucchini can prevent Fe deficiency in the host of the agent, but cannot prevent the spread of infection (Graham and Webb, 1991; Röhmeld and Marschner, 1991). Zinc can have a wide range of effects on plant disease susceptibility. In some cases, the severity and prevalence of the disease decrease, while in some cases it may not have any effect on the current situation (Graham and Webb, 1991; Grewal et al., 1996). Zn application can reduce disease severity in many cases due to its direct toxic effect on pathogens rather than plant metabolism (Graham and Webb, 1991). The role of Zn in the enrichment of growth parameters may be to increase resistance to rust diseases in wheat. This resistance is formed by the combination of three enzymes (carbonic anhydrase, alcohol dehydrogenase, and superoxide dismutase). Furthermore, zinc has a significant impact on the plant's "auxin" level (Ohki, 1978). Auxin stimulates meristematic activity in plants, resulting in increased cell division and expansion (Devlin and Witham, 1983). In addition to the protein content of the grain, the use of these elements can increase the concentrations of Fe, Mn, and Zn in the grain and flag leaf. According to Potarzycki and Grzebisz (2009), Zn has a significant impact on the plant's life cycle. It is known that protein synthesis and protein content decrease in plants with Zn deficiency. According to Morsy (2012), zinc, calcium, and manganese applications had a positive effect on faba bean growth (plant height) and yield (number of plants per plot and 100 seed weight). It has been reported in many cases that the effect of Zn application may not be on plant metabolism, but on disease severity reduction due to its direct toxic effect on pathogens (Graham and Webb, 1991). Increased disease severity was observed compared to the control group with zinc deficient Hevea brasiliensis, Oidium spp. (Bolle-Jones and Hilton, 1956).

The aims of this study are to have information about the severity of rust diseases (%DI) for different phenological periods in wheat, to reveal disease scores for disease symptoms occurring under mineral fertilizer applications, and to determine resistance classes according to infection coefficient values corresponding to disease severity according to different disease color changes. On the other hand, in this study; it is important to determine the Fe and Zn application doses that can be used in the fight against the disease in the early period, which will prevent the development of the disease in the early period for different development stages of wheat.

## Material and Methods

### Climatic and Soil Characteristics of the Experimental Area

The monthly average climate data (OMNI-Meteorology) of 2018-2019 for the location of Ankara Yenimahalle district, where the research was carried out is given below (Table 1). Considering the monthly total precipitation and temperature amounts for 2018-2019, it was determined that the monthly average precipitation was 33.2 mm, and the monthly average temperature was 12.08 °C. The texture of the soil was determined as clay loam.

### Plant Materials

The Central Research Institute of Field Crops, Ankara, to investigate the seasonal effects of yellow rust (*Puccinia striiformis* f. sp. *tritici*) with hyperspectral data (multi-band) and to be tested under artificial epidemics, sensitive and resistant to yellow rust disease, registered the plants used in the experiment. Varieties with known resistant reactions and high reactions to fertilizer application were chosen as test materials (Table 2). In addition, "*Little Club*" was planted among the varieties as a sensitive control group genotype plant in the study. In this way, it was possible to simultaneously collect spectral data on susceptible and resistant varieties to yellow rust disease and compare each other. All planting was done by hand.

**Table 1.** Average monthly climate data of Yenimahalle district for the year 2018-2019

| Climate data | Month (2018 Year) | | | | Month (2019 Year) | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aug. | Sep. | Oct. | Nov. | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | |
| Mean Temperature (°C) | 20.0 | 14.94 | 9.0 | 3.3 | 2.0 | 4.8 | 7.2 | 10.8 | 18.2 | 22.4 | 23.1 | 12.08 |
| Highest temperature , °C | 33.2 | 21.65 | 23.5 | 12.6 | 10.8 | 15.8 | 20.4 | 25.5 | 34.2 | 33.4 | 34.9 | 24.43 |
| Lowest temperature , °C | 8.1 | 9.43 | -2.3 | -10.2 | -10.4 | -2.4 | -3.3 | -0.9 | 6.1 | 11.7 | 10.7 | 0.71 |
| Mean precipitation ş, mm | 7.4 | 1.57 | 24.9 | 60.4 | 40.6 | 33.2 | 38.0 | 28.9 | 30.8 | 37.4 | 30.4 | 33.2 |
| Relative humidity , % | 46 | 69.83 | 65 | 81 | 79 | 70.2 | 55.4 | 42.5 | 47.2 | 52.1 | 42.0 | 58.04 |
| Wind speed , m/s (2 m) | 2.1 | 2.2 | 1.6 | 1.5 | 1.7 | 2.0 | 2.1 | 1.3 | 1.3 | 1.6 | 1.8 | 1.7 |

**Table 2**. Some characteristics of bread wheat varieties used in the study

| Bread Group | | |
|---|---|---|
| Variety | Registration year | Disease reactions |
| Bayraktar 2000 | 28.04.2000 | Moderately Sensitive |
| Demir 2000 | 28.04.2000 | Sensitive |
| Eser | 02.05.2003 | Resistant |
| Kenanbey | 06.04.2009 | Sensitive |

- Little Club (sensitive) precision control genotype plant was planted between varieties.

### Trial Design and Fertilizer Application Times

For the fertilizer-applied disease garden, four rows were planted from each variety. The test material was sown by hand on 14 November 2018 in 4 rows (20 kg/da seed) with 2.5-3 g seeds per row. With the planting, diammonium phosphate (DAP) 6.3 g/0.45 m²) fertilizer was applied with an account of 14 kg/da. In the calculation of the application dose to be given to the parcel for iron (Fe) and zinc (Zn) and iron+zinc (Fe+Zn) fertilizer applications, the parcel width is 0.60 m and the parcel length is 10 m was calculated. Fe, Zn, and Fe+Zn doses were applied in different phenological periods, starting from the tillering period, in a total of 6 applications. Dosage for Fe fertilization applications; It is prepared to be given to 1 decare by dissolving 75-100 g Fe-6 Forte (GÜBRETAŞ) in 100 liters of water. Accordingly, for three different fertilizer application doses for Fe; in the first application, 5g/5L/6m$^2$ Fe, II. In application 10g/5L/6m$^2$ Fe, III. In the application, 20 g/5L/6m$^2$ Fe was calculated and fertilizer application was made. Dose for Zn fertilization applications; Starting from the tillering period, it was applied 6 times in the form of Powder-Forte with the calculation of 150 g/100L water/1 da (0.60 m*10 m = 6 m2). In the first application, 7.5g / 5L/6m$^2$ Zn, II. 15g/5L/6m$^2$ Zn in practice, III. In the application, 30 g / 5lt / 6m$^2$ Zn was applied. Dose for Fe+Zn fertilization applications; was made by starting from the tillering period and dividing it into 6 application periods. In the first application, Fe 5g/5L+Zn7.5g/5L II. in practice, Fe 10g/5L+Zn15g/5L and III. in the application, Fe 20g/5L+Zn30g/5L fertilizer doses were applied (Table 3).

### Disease Inoculation

Disease inoculation was done following the "National Plant Protection Standards" for field stage studies (Li et al., 1989). On May 6, 2019, the first inoculation was made (Feekes 6), which can be considered as the plant's stemming period. The second inoculation of rust was done on May 13, 2019 (pre-flowering period, Feekes 10), seven days after the first application. Freshly produced rust spores were used for disease inoculation and it was aimed to obtain the highest viable spore in this way. Disease inoculation was made especially in windless weather, and plastic barriers (shields) were used between the blocks to prevent the application dose from passing to the other

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**Table 3.** Mineral fertilizer application doses and dates for bread wheat varieties

| Application Dates | Fertilizer Applications | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I. Application* | | | II. Application* | | | III. Application* | | |
| | Fe | Zn | Fe+Zn | Fe | Zn | Fe+Zn | Fe | Zn | Fe+Zn |
| 21.03.2019 | 5 g/5L | 7.5g/5L | 12.5g/5L | 10g/5L | 15g/5L | 25g/5L | 20g/5L | 30g/5L | 50 g/5L |
| 02.04.2019 | 5g/5L | 7.5g/5L | 12.5g/5L | 10g/5L | 15g/5L | 25g/5L | 20g/5L | 30g/5L | 50 g/5L |
| 16.04.2019 | 5g/5L | 7.5g/5 | 12.5g/5L | 10g/5L | 15g/5L | 25g/5L | 20g/5L | 30g/5L | 50 g/5L |
| 29.04.2019 | 5g/5L | 7.5g/5L | 12.5g/5L | 10g/5L | 15g/5L | 25g/5L | 20gr5L | 30g/5L | 50 g/5L |
| 06.05.2019 | 5g/5L | 7.5g/5L | 12.5g/5L | 10g/5L | 15g/5L | 25g/5L | 20g/5L | 30g/5L | 50 g/5L |
| 13.05.2019 | 5g/5L | 7.5g/5L | 12.5g/5L | 10g/5L | 15g/5L | 25g/5L | 20g/5L | 30g/5L | 50 g/5L |

I*. Application: Fe 833.33 g/da, Zn 1.250 kg/da, II*. Application: Fe 1.667 kg/da, Zn 2.500 g/da, III*. Application: Fe 3.333 kg/da Zn 5.000 kg/da
Mineral fertilizer applications were calculated as g/6 $m^2$ for each parcel (0.60 m*1.0 m=6 $m^2$).

parcel. Yellow rust inoculation was made to determine the reactions of different doses of fertilizer applications ($Fe_5$, $Fe_{10}$, $Fe_{20}$, $Zn_{7.5}$, $Zn_{15}$, $Zn_{30}$, Fe+Zn $_{(5+7.5)}$, Fe+Zn $_{(10+15)}$, Fe+Zn $_{(20+30)}$) to yellow rust disease. Yellow rust disease spores were applied as 2.0 g/200 ml for three replications in all fertilizer applications and the disease was inoculated twice with the ULV+ device, 172 and 179 days after sowing (06 May 2019 and 13 May 2019). Disease inoculation was carried out, especially in windless weather.

**Field Observations, Leaf Sampling and Evaluation of Disease Reactions**

Field observations were taken at different phenological development stages (Feekes) of all test material cultivated in the application areas (Large, 1954). Observations were made in 4 periods, from 25 May to 23 June 2019, in which disease reactions were evaluated (first part). These periods are; at the beginning of flowering (Feekes 10.5.1), during the grain filling period (Feekes 10.5.3), during the milking period (Feekes 10.5.4) and the Yellowing period (Feekes 11.1) (Fowler, 2018) (Table 4).

**Table 4.** Date and phenological periods of leaf samples taken

| Sampling Dates | Different development stages | Feekes | Zadoks scale |
|---|---|---|---|
| 25 May 2019 | Flowering Beginning (Early Period) | 10.5.1 | 60 |
| 06 June 2019 | Grain Binding (Early-Middle Period) | 10.5.3 | 69 |
| 15 June 2019 | Milk Settlement Period (Middle-Late Period) | 10.5.4 | 71 |
| 23 June 2019 | Ripening Period (Late Period) | 11.1 | 75 |

Leaf samples were collected from the inoculated and non-inoculated plots once every 7 days (25 May 2019, 06 June 2019, 15 June 2019) 19 days after the yellow rust disease inoculation (06 May 2019). (Table 4). A total of 60 leaves were collected from three replications, with 20 leaves from each replication (4 types *5 leaf sample"s). To make the same application in the collection of leaf samples, the third leaf of the plant was taken from the top, but in cases where sampling was not possible in this way, the second leaf from the top was taken as a sample. In each sampling period (4 terms) 240 plant leaf samples were collected from 4 blocks (20 sample-no fertizer+60 samples*3 blocks). In addition to this study, a total of 40 leaves (8 plots*5 leaves) were collected from 6 plots of the precision control Little Club variety, and the number of leaf samples reached 240 (200+40). The samples for counting were placed in paper envelopes and kept in the refrigerator until the study was completed. To determine the degree of mean severity of the disease, one means disease score was calculated for 5 leaves collected for each variety from each replication. In this way, one means disease severity was calculated for each variety. A disease score was determined for each variety by subjecting the images of the leaf sample taken with a digital and thermal camera to a controlled classification (Supervised Classification) in the "Image Classification" image classification module in ArcGIS 10.5.1 Program. Disease severity (%DI) was obtained by dividing the diseased area covered by yellow rust disease on the leaf by the total leaf area and multiplying by the activity coefficient. In the disease evaluations, the plants were divided into 9 classes according to the disease severity of the diseased area (0%, 1%, 10%, 20%, 30%, 45%, 60%, 80%, and 100%). A value of 0% indicates that no disease was detected, and

100% indicates the class of the most severe disease (the leaf is completely covered with disease). The disease indice (Di%) was calculated with the following formula (Huang et al., 2007) (1). Disease Severity (DS) is calculated by multiplying the disease indice (Di%) with the infection coefficient (IC) into which the reaction type is included (Table 5) (2).

**Table 5.** Types of plant reactions against yellow rust disease in wheat (Roelfs et al., 1992)

| Reaction Types | Infection Coefficients | Description |
|---|---|---|
| 0 | 0 | No visible infection. |
| R (Resistant) | 0,2 | There are necrotic (dead tissue) spots. These do not have rust pustules or are very small. |
| MR (Moderately) Resistant) | 0,4 | Small pustules surrounded by necrotic areas are seen. |
| MS (Moderately Sensitive) | 0,8 | Small to medium sized pustules are seen. There are no necrotic spots, there are obvious chlorotic spots. |
| S (Sensitive) | 1 | There are large pustules, no necrotic or chlorotic areas. |

$$Di\ (\%) = \frac{\sum xf}{n \sum f} x100 \qquad \textbf{(1)}$$

***Di (%)***= Disease indice

***n***= Highest disease severity value

***f***= Number of leaves per disease severity grade

$$DI\ (\%) = Di\ (\%)\ x\ IC \qquad \textbf{(2)}$$

***DS (%)*** = Disease Severity

***IC*** = Infection Coefficient

Yellow rust's severity and the reaction types (Roelfs et al., 1992) of plants against yellow rust disease were also recorded using the Modified Cobb scale (Peterson et al., 1948) on the collected leaf samples (Table 5). It has been classified into 5 groups according to the infection coefficients (IC) reactions (Disease Severity %DS) (Immune: 0 EK, Resistant: 0.1-5.0, Moderately resistant: 5.0-20.0, Moderately susceptible: 20.1-40.0, Sensitive: 41.0-100.0) (Akan, 2019).

To calculate the change in disease severity of different mineral fertilizer applications ($Fe_5$, $Fe_{10}$, $Fe_{20}$) applied according to phenological periods, the difference between the disease severity value obtained as a result of the applied fertilizer dose application, based on the 0% dose without mineral fertilizer applied (control), is multiplied by 100, and the % increase rate is calculated by dividing the disease severity value (%DI) of the application without fertilizer.

## Results and Discussion

### Investigation of Disease Severity Change under Mineral Fertilizer Applications (Fe, Zn, Fe+Zn) in Bread Varieties

The use of plant nutrients, especially against plant pathogens, has gained importance in terms of increasing tolerance or resistance to diseases (Graham and Webb, 1991). All plant nutrients affect disease severity to varying degrees (Huber and Graham, 1999b). However, while not a general rule, any specific nutrient can reduce or increase the severity of any plant disease depending on the severity of other diseases in the environment and environmental conditions. (Huber, 1980a; Marschner, 1995; Graham and Webb, 1991). Despite the recognition of the importance of plant nutrients in the control of many important plant diseases, proper fertilizer management strategies in sustainable agriculture have always received less attention. Iron applications increase the tolerance against Sphaeropsis malorum in apples and pears and pumpkin against Olpidium brassicas. Furthermore, additional fertilizer application in zucchini can prevent Fe deficiency in the agent's host but cannot prevent infection spread (Graham and Webb, 1991; Römheld and Marschner, 1991). Zinc (Zn) applications have very different interactions in the reactions of plants against diseases. It has been reported that in some cases it reduces the effect of the disease on the plant, and in some cases, it increases the effect of the disease on the plant or has no effect (Graham and Webb, 1991; Grewal et al., 1996). In many cases, It has been reported that Zn application may have an effect on disease severity rather than plant metabolism due to its direct toxic effect on pathogens (Graham and Webb, 1991).

When all phenological periods are evaluated together; in Eser variety a decrease in the disease reaction was determined (Tukey B*HSD Test). Among all Fe dose applications, $Fe_{10}$ and $Fe_{20}$ doses caused the greatest reduction in disease severity (-28.57% and -22.23% respectively) in the early period. Similarly, in the mid-late period, it was determined that the dose of $Fe_{20}$ fertilizer caused a decrease in disease severity (-22.23%) (Tables 6 and 8). It was determined that in early, early-middle, and mid-late periods, applications of $Zn_{7.5}$ and $Zn_{15}$ fertilizer doses had a significant effect on disease severity with $p \leq 0.05$. It was determined that the application of $Zn_{7.5}$ and $Zn_{15}$ fertilizer doses in the early period had an increasing (+28.58% and +14.29%) effect on disease severity. It was determined that the application of $Zn_{15}$ fertilizer dose in the early-middle and mid-late period increased the severity of the disease (+16.67%), while the application of $Zn_{20}$ and $Zn_{7.5}$ fertilizer doses decreased the disease severity (-22.23%) (Tables 7 and 8). Basic statistical analysis of variation (ANOVA) for all phenological periods was

**Table 6.** According to different phenological periods for mineral fertilizer applications (Fe, Zn, Fe+Zn) disease change rates (%) (Eser 2019)

| | Phenological Periods | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Eser Variety | 25 May 2019 (10.5.1) | | 06 June 2019 (10.5.3) | | 15 June 2019 (10.5.4) | | 23 June 2019 (11.1.1) | | Mean | |
| Application | % DS | % Change | % DS | % Change | % DS | % Change | % DS | % Change | % DS | % Change |
| No Fertilizer (Control) | 9.333 | - | 12.00 | - | 12.00 | - | 0.00 | - | 8.33 | - |
| Fe 5g/5 L | 8.000 | -14.26 | 9.333 | -22.23 | 12.00 | 0.00 | 0.00 | 0.00 | 7.33 | -18.24 |
| Fe 10 g/5 L | 6.667 | -28.57 | 12.00 | 0.00 | 12.00 | 0.00 | 0.00 | 0.00 | 7.67 | -7.14 |
| Fe 20 g/5 L | 6.667 | -28.57 | 9.333 | -22.23 | 9.333 | -22.23 | 0.00 | 0.00 | 6.33 | -3.97 |
| Zn 7.5 g/5 L | 12.000 | +28.58 | 9.333 | -22.23 | 9.333 | -22.23 | 0.00 | 0.00 | 7.67 | -3.97 |
| Zn 15 g /5 L | 10.667 | +14.29 | 14.00 | +16.67 | 14.00 | +16.67 | 0.00 | 0.00 | 9.67 | +11.91 |
| Zn 30 g/5 L | 9.333 | 0.00 | 12.00 | 0.00 | 12.00 | 0.00 | 0.00 | 0.00 | 8.33 | 0.00 |
| Fe+Zn 5+7.5 g/5 L | 8.000 | -14.28 | 12.00 | 0.00 | 12.00 | 0.00 | 0.00 | 0.00 | 8.00 | -3.57 |
| Fe+Zn 10+15g/5 L | 9.333 | 0.00 | 12.00 | 0.00 | 12.00 | 0.00 | 0.00 | 0.00 | 8.33 | 0.00 |
| Fe+Zn 20+30g/5 L | 9.333 | 0.00 | 12.00 | 0.00 | 12.00 | 0.00 | 0.00 | 0.00 | 8.33 | 0.00 |

**Table 7.** Multiple comparison (ANOVA) variance analysis results of the effects of different mineral fertilizer applications (Fe, Zn, Fe+Zn) on disease reaction in Eser variety

| Perods (Feekes) | | 10.5.1 | 10.5.3 | 10.5.4 | 11.1.1 |
|---|---|---|---|---|---|
| Eser | | 25 May 2019 | 06 June 2019 | 15 June 2019 | 23 June 2019 |
| | | Disease Severity, % DI (Average ± SD) | | | |
| Doses | Rec. | (DAS-185) | (DAS-197) | (DAS-206) | (DAS-214) |
| 0 | 12 | 9.33±0.57 a | 12.00±0.00 a | 12.00±0.00 a | 0.00±0.00 a |
| Fe5 | 12 | 8.00±0.00 a | 9.33±0.57 b | 12.00±0.00 a | 0.00±0.08 a |
| Fe10 | 12 | 6.67±1.14 a | 12.00±0.00 a | 12.00±0.00 a | 0.00±0.00 a |
| Fe20 | 12 | 6.67±1.14 a | 9.33±0.57 b | 9.33±0.57 b | 0.00±0.00 a |
| Sig. | 48 | 0.136 | 1.000 | 1.000 | 0.497 |
| 0 | 12 | 9.33±0.57 b | 12.00±0.00 b | 12.00±0.00 b | 0.08±0.00 a |
| Zn7.5 | 12 | 12.00±0.00 a | 9.33±0.57 c | 9.33±0.57 c | 0.00±0.00 a |
| Zn15 | 12 | 10.67±1.97 ab | 14.00±0.85 a | 14.00±0.85 a | 0.00±0.00 a |
| Zn30 | 12 | 9.33±1.97 b | 12.00±0.00 b | 12.00±0.00 b | 0.00±0.00 a |
| Sig. | 48 | 0.237 | 0.237 | 1.000 | 0.497 |
| | 12 | 9.33±0.57 a | 12.01±0.01 a | 12.01±0.01 a | 0.08±0.00 a |
| Fe+Zn(5+7.5) | 12 | 8.00±0.00 a | 12.00±0.00 a | 12.00±0.00 a | 0.00±0.00 a |
| Fe+Zn(10+15) | 12 | 9.33±0.80 a | 12.00±0.00 a | 12.00±0.00 a | 0.00±0.00 a |
| Fe+Zn(20+30) | 12 | 9.33±0.80 a | 12.00±0.00 a | 12.00±0.00 a | 0.00±0.00 a |
| Sig. | 48 | 0.497 | 0.497 | 0.497 | 0.497 |

Mean.: Mean Disease Intensity (%DI), SD: Average Standart Deviation DAS: Day After Sowing
Successive lowercase letters in the same column indicate differences between doses within the same phenological period.
Consecutivelowercase letters are not statistically significant (Tukey Post hoc test)
* The difference in the mean is significant at the $p \leq 0.05$ level (Tukey's HSD test ($p < 0.05$).

**Table 8.** According to phenological periods disease severity (%DS) evaluations at repetitive fertilizer application (Fe, Zn, Fe+Zn) doses Anova Results in Eser variety

| Eser Variety | Phenological Periods (Feekes) | RMSE | df | MSE | F | Sig. (P) |
|---|---|---|---|---|---|---|
| Fe | 10.5.1 | 58.667 | 3 | 19.556 | 2.241 | 0.097 |
| | 10.5.3 | 85.833 | 3 | 28.444 | 14.667 | 0.000 |
| | 10.5.4 | 64.000 | 3 | 21.333 | 22.000 | 0.000 |
| | 11.1 | 0.01 | 3 | 0.000 | 1.000 | 0.402 |
| Zn | 10.5.1 | 58.667 | 3 | 19.556 | 6.722 | 0.001 |
| | 10.5.3 | 132.000 | 3 | 44.000 | 13.962 | 0.000 |
| | 10.5.4 | 132.000 | 3 | 44.000 | 13.962 | 0.000 |
| | 11.1 | 0.01 | 3 | 0.000 | 1.000 | 0.402 |
| Fe+Zn | 10.5.1 | 16.000 | 3 | 5.333 | 0.917 | 0.441 |
| | 10.5.3 | 0.001 | 3 | 0.000 | 1.000 | 0.402 |
| | 10.5.4 | 0.001 | 3 | 0.000 | 1.000 | 0.402 |
| | 11.1 | 0.001 | 3 | 0.000 | 1.000 | 0.402 |

RMSE: Error Sum of Squares F: Comparison Table Value of Sample Means df: Degrees of Freedom
MSE: Error Mean Squares Sig.(p): Significance Level in Comparison

**Table 9.** According to different phenological periods for mineral fertilizer applications (Fe, Zn, Fe+Zn) disease change rates (%) in Kenanbey variety

| | Phenological Periods | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Kenanbey Variety | 25 May 2019 (10.5.1) | | 06 June 2019 (10.5.3) | | 15 June 2019 (10.5.4) | | 23 June 2019 (11.1.1) | | Mean | |
| Application | % DS | % Change | % DS | % Change | % DS | % Change | % DS | % Change | % DS | % Change |
| No Fertilizer (0) | 18.67 | - | 48.00 | - | 69.00 | - | 87.00 | - | 55.67 | - |
| Fe 5g/5 L | 32.00 | +71.40 | 51.00 | +6.25 | 69.00 | 0.00 | 90.00 | +3.45 | 60.50 | +8.68 |
| Fe 10g/5 L | 16.00 | -14.30 | 51.00 | +6.25 | 60.00 | -13.04 | 81.00 | -6.90 | 52.00 | -6.59 |
| Fe 20g/5 L | 24.00 | +28.55 | 45.00 | -6.25 | 69.00 | 0.00 | 84.00 | -3.45 | 55.50 | -0.31 |
| Zn 7.5g/5 L | 32.00 | +71.40 | 45.00 | -6.25 | 54.00 | -21.74 | 81.00 | -6.90 | 53.00 | -4.80 |
| Zn 15g/5 L | 25.33 | +35.67 | 51.00 | +6.25 | 66.00 | -4.35 | 84.00 | -3.45 | 56.58 | +1.63 |
| Zn 30g/5 L | 20.00 | +7.12 | 45.00 | -6.25 | 57.00 | -17.39 | 72.00 | -17.24 | 48.50 | +12.88 |
| Fe+Zn 5+7.5g/5 L | 22.67 | +21.42 | 51.00 | +6.25 | 75.00 | +8.70 | 84.00 | -3.45 | 58.17 | +4.49 |
| Fe+Zn 10+15g/5 L | 22.00 | +17.84 | 39.00 | -18.75 | 60.00 | -13.04 | 72.00 | -17.24 | 48.25 | -13.33 |
| Fe+Zn 20+30g/5 L | 26.67 | +42.85 | 45.00 | -6.25 | 69.00 | 0.00 | 84.00 | -3.45 | 56.17 | +0.90 |

performed using SPSS-22® version statistical package program (IBM SPSS Statistics, 2014).

A limited decrease in disease severity (-14.28%) was observed in Fe+Zn $_{(5+7.5)}$ fertilizer application in the early period, while no significant change was detected in all other phenological periods (Table 8).

In the bread Ekmeklik Kenanbey variety; The differences between the disease reactions in Fe fertilizer dose applications, the early and early-mid periods, in particular, were found to be statistically significant ($p<0.05$) and an increase in the severity of the disease was determined with the advancing biological process (Table 10). It was determined that $Fe_5$ and $Fe_{20}$ doses of Fe fertilizer dose applications caused the highest increase (+71.40%, +28.55%) in the disease reaction severity in the early period. In the early-middle period (06 June 2019), an increase in the disease severity was observed at the $Fe_5$ and $Fe_{10}$ fertilizer application doses (+6.25%), and a decrease in the disease severity was observed at the $Fe_{10}$ fertilizer application dose in the mid-late period (-13.04%) (Table 9). Among the Zn applications, the differences between the disease reactions at the fertilizer application doses of $Zn_{7.5}$, $Zn_{15}$, and $Zn_{30}$ in the early period were found to be statistically significant. It was determined that $Zn_{7.5}$, $Zn_{15}$, and $Zn_{30}$ fertilizer application doses were effective in increasing the disease reaction severity (+71.40%, +35.67%, +7.12%) in the early period. In the early-middle period, an increase in disease severity was observed at the $Zn_{15}$ fertilizer application dose (+6.25%), and a decrease in the disease severity at $Zn_{7.5}$ and $Zn_{30}$ fertilizer application doses (-6.25%) (Table 9). In the mid-late period, a decrease in disease severity was determined at all Zn fertilizer application doses ($Zn_{7.5}$, $Zn_{15}$, $Zn_{30}$) (-54%, -66%, -57%). It was determined that different Fe+Zn fertilizer application doses caused

**Table 10.** Multiple comparison (ANOVA) variance analysis results of the effects of different mineral fertilizer applications (Fe, Zn, Fe+Zn) on disease reaction in Kenanbey variety

| Periods (Feekes) Kenanbey Variety | | 10.5.1 25 May 2019 | 10.5.3 06 June 2019 | 10.5.4 15 June 2019 | 11.1.1 23 June 2019 |
|---|---|---|---|---|---|
| | | Disease Severity, % DS (Average ± SD) | | | |
| Doses | Rec. | (DAS-185) | (DAS-197) | (DAS-206) | (DAS-214) |
| 0 | 12 | 18.67±2.84 ab | 48.00±1.28 ab | 69.00±1.28 a | 87.00±1.28 ab |
| Fe5 | 12 | 32.00±0.00 a | 51.00±1.28 a | 69.00±1.28 a | 90.00±0.00 a |
| Fe10 | 12 | 16.00±1.71 c | 51.00±1.28 a | 60.00±1.28 a | 81.00±0.00 c |
| Fe20 | 12 | 24.00±0.00 b | 45.00±0.00 b | 69.00±2.56 b | 84.00±1.28 bc |
| Sig. | 48 | 0.261 / 1.000 | 0.237 | 1.000 | 0.103 |
| 0 | 12 | 18.67±2.84 b | 48.00±1.28 ab | 69.00±1.279 a | 87.00±1.28 a |
| Zn7.5 | 12 | 32.00±0.00 a | 45.00±0.00 b | 54.00±0.000 b | 81.00±0.00 b |
| Zn15 | 12 | 25.33±2.84 ab | 51.00±1.28 a | 66.00±1.279 a | 84.00±1.28 ab |
| Zn30 | 12 | 20.00±0.85 b | 45.00±0.00 b | 57.00±1.279 b | 72.00±0.00 c |
| Sig. | 48 | 0.115 | 1.000 | 0.237 | 1.000 |
| 0 | 12 | 18.67±2.84 b | 48.00±1.28 ab | 69.00±1.28 a | 87.00±1.28 a |
| Fe+Zn5+7.5 | 12 | 22.67±1.99 ab | 51.00±1.28 a | 75.00±1.28 a | 84.00±1.28 a |
| Fe+Zn10+15 | 12 | 22.00±0.85 ab | 39.00±1.28 c | 60.00±1.28 b | 72.00±0.00 b |
| Fe+Zn20+30 | 12 | 26.67±1.14 a | 45.00±0.00 b | 69.00±2.56 a | 84.00±0.00 a |
| Sig. | 48 | 0.441 / 0.306 | 1.000 / 0.237 | 1.000 / 0.073 | 1.000 / 0.237 |

**Table 11.** According to phenological periods disease severity (%DI) evaluations at repetitive fertilizer application (Fe, Zn, Fe+Zn) doses Anova results in Kenanbey variety

| Kenanbey Variety | Phenological Periods (Feekes) | RMSE | df | MSE | F | Sig. (P) |
|---|---|---|---|---|---|---|
| Fe | 10.5.1 | 1792 | 3 | 597.333 | 18.118 | 0.000 |
| | 10.5.3 | 297.000 | 3 | 99.000 | 6.722 | 0.001 |
| | 10.5.4 | 729.000 | 3 | 243.000 | 7.071 | 0.001 |
| | 11.1 | 540.000 | 3 | 180.000 | 18.333 | 0.000 |
| Zn | 10.5.1 | 1322.667 | 3 | 440.889 | 8.702 | 0.000 |
| | 10.5.3 | 297.000 | 3 | 99.000 | 10.083 | 0.000 |
| | 10.5.4 | 1836.000 | 3 | 612.00 | 41.556 | 0.000 |
| | 11.1 | 1512.000 | 3 | 504.000 | 51.333 | 0.000 |
| Fe+Zn | 10.5.1 | 388.000 | 3 | 129.333 | 3.066 | 0.038 |
| | 10.5.3 | 945.000 | 3 | 315.000 | 21.389 | 0.000 |
| | 10.5.4 | 1377.000 | 3 | 459.000 | 13.357 | 0.000 |
| | 11.1 | 1593.000 | 3 | 531.000 | 36.056 | 0.000 |

RMSE: Error Sum of Squares F: Comparison Table Value of Sample Means df: Degrees of Freedom
MSE: Error Mean Squares Sig.(p): Significance Level in Comparison

an increase in disease severity in the early period, and the highest increase was in the Fe+Zn $_{(20+30)}$ application dose. This was followed by Fe+Zn $_{(5+7.5)}$ and Fe+Zn $_{(10+15)}$ doses, respectively (+21.42%, +17.64%). In the early-middle and mid-late periods, a limited increase in disease severity was observed at the Fe+Zn $_{(5+7.5)}$ application dose (+6.25%, +8.70%), and it was determined that there was a decrease in the disease severity at all other doses and application periods (Table 9). In Bayraktar 2000 variety, the highest increase in disease severity (+49.95%) was observed in Fe+Zn$_{(10+15)}$ application in the early-middle period due to increasing fertilizer doseapplications.

It was determined that this situation was followe d by Zn15 (+37.49%), Fe5, and Fe10 fertilizer dose applications (+37.49%) in the same period. In the mid-late period, an increase in disease severity was observed in the application of Fe5 and Fe10, and Fe+Zn $_{(10+15)}$ fertilizer doses (+20.03%) (Table 12). Significant reductions in the severity of the disease were determined most in the early-middle and mid-late periods at the Zn30 application dose (- 50.05%, -39.98%) (Table 12 and 14).

**Table 12.** According to different phenological periods for mineral fertilizer applications (Fe, Zn, Fe+Zn) disease change rates (%) in Bayraktar 2000 variety

| Bayraktar 2000 Variety | Phenological Periods 25 May 2019 (10.5.1) | | 06 June 2019 (10.5.3) | | 15 June 2019 (10.5.4) | | 23 June 2019 (11.1.1) | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| Application | % DS | % Change | % DS | % Change | % DS | % Change | % DS | % Change | % DS | % Change |
| No Fertilizer (Control) | 6.67 | 0.00 | 10.67 | 0.00 | 13.33 | 0.00 | 0.00 | 0.00 | 7.67 | 0.00 |
| Fe 5g/5 L | 8.00 | +19.94 | 14.67 | +37.49 | 16.00 | +20.03 | 0.80 | +80 | 9.87 | +28.68 |
| Fe 10g/5 L | 5.33 | -20.09 | 14.67 | +37.49 | 16.00 | +20.03 | 0.80 | +80 | 9.20 | +19.95 |
| Fe 20g/5 L | 5.33 | -20.09 | 10.67 | 0.00 | 10.67 | +19.95 | 4.00 | +400 | 7.67 | 0.00 |
| Zn 7.5g/5 L | 4.00 | -40.03 | 10.67 | 0.00 | 10.67 | +19.95 | 0.80 | +80 | 6.54 | +14.73 |
| Zn 15g/5 L | 6.67 | 0.00 | 14.67 | +37.49 | 14.67 | +10.05 | 0.80 | +80 | 9.20 | +19.95 |
| Zn 30g/5 L | 6.67 | 0.00 | 5.33 | -50.05 | 8.00 | -39.98 | 4.00 | 400 | 6.00 | +21.77 |
| Fe+Zn 5+7.5g/5 L | 5.33 | -20.09 | 12.00 | +12.46 | 13.33 | 0.00 | 4.00 | +400 | 8.67 | +13.04 |
| Fe+Zn 10+15g/5 L | 7.33 | +9.90 | 16.00 | +49.95 | 16.00 | +20.03 | 4.00 | +400 | 10.83 | +41.20 |
| Fe+Zn 20+30g/5 L | 9.33 | +39.88 | 10.67 | 0.00 | 10.67 | -19.95 | 4.00 | +400 | 8.67 | +13.04 |

When all phenological periods were evaluated together, the effects of Fe applications were found to be statistically significant (p≤0.05), as were the differences in disease reactions, especially in the early and early-mid periods, were observed to increase in disease severity (Table 13).

High Zn dose applications (Zn30) showed reductions in disease severity in the early-middle and mid-late periods. Significant increases in disease reactions were determined in all phenological development periods in the late period, and the most significant increase was determined in the Fe+Zn fertilizer application dose in the late period (Table 13).

**Table 13.** Multiple comparison (ANOVA) variance analysis results of the effects of different mineral fertilizer applications (Fe, Zn, Fe+Zn) on disease reaction in Bayraktar 2000 variety

| Periods (Feekes) | | 10.5.1 | 10.5.3 | 10.5.4 | 11.1.1 |
|---|---|---|---|---|---|
| Bayraktar 2000 | | 25 May 2019 | 06 June 2019 | 15 June 2019 | 23 June 2019 |
| | | Disease Severity, % DS (Average ± SD) | | | |
| Doses | Rec. | (DAS-185) | (DAS-197) | (DAS-206) | (DAS-214) |
| 0 | 12 | 6.67±0.57 ab | 10.67±0.57 b | 13.33±0.57 b | 0.00±0.00 c |
| Fe5 | 12 | 8.00±0.00 a | 14.67±0.57 a | 16.00±0.00 a | 8.00±0.00 b |
| Fe10 | 12 | 5.33±0.28 b | 14.67±1.42 a | 16.00±0.85 a | 8.00±0.00 b |
| Fe20 | 12 | 5.33±0.57 b | 10.67±0.57 c | 10.67±0.57 c | 4.00±0.00 a |
| Sig. | 48 | 0.136 | 1.000 | 1.000 | 1.000 |
| 0 | 12 | 6.67±0.57 a | 10.67±0.57 b | 13.33±0.57 ab | 0.00±0.00 c |
| Zn7.5 | 12 | 4.00±0.00 b | 10.67±0.57 b | 10.67±0.57 bc | 8.00±0.00 b |
| Zn15 | 12 | 6.67±0.57 a | 14.67±1.42 a | 14.67±1.427 a | 8.00±0.00 b |
| Zn30 | 12 | 6.67±0.28 b | 5.33±0.57 c | 8.00±0.007 c | 4.00±0.00 a |
| Sig. | 48 | 0.115 | 1.000 | 0.111 / 0.658 | 1.000 |
| 0 | 12 | 6.67±0.57 ab | 10.67±0.57 b | 13.33±0.568 b | 0.00±1.28 b |
| Fe+Zn5+7.5 | 12 | 5.33±0.57 b | 12.00±0.01 b | 13.33±0.568 b | 4.00±1.28 a |
| Fe+Zn10+15 | 12 | 7.33±0.29 ab | 16.00±0.86 a | 16.00±0.852 a | 4.00±0.00 a |
| Fe+Zn20+30 | 12 | 9.33±1.14 a | 10.67±0.57 b | 10.67±0.568 c | 4.00±0.00 a |
| Sig. | 48 | 0.207 / 0.052 | 0.384 /1.000 | 1.000 | - |

**Table 14.** According to phenological periods Disease Severity *(%DI)* evaluations at repetitive fertilizer application (Fe, Zn, Fe+Zn) doses Anova results in Bayraktar 2000 variety

| | Phenological | | | | | |
|---|---|---|---|---|---|---|
| Bayraktar 2000 | Periods (Feekes) | RMSE | df | MSE | F | Sig. (P) |
| Fe | 10.5.1 | 58.667 | 3 | 19.556 | 8.963 | 0.001 |
| | 10.5.3 | 192.000 | 3 | 64.000 | 7.135 | 0.001 |
| | 10.5.4 | 234.667 | 3 | 78.222 | 18.980 | 0.000 |
| | 11.1 | 113.280 | 3 | 37.760 | 11.134 | 0.000 |
| Zn | 10.5.1 | 64.000 | 3 | 21.333 | 9.778 | 0.000 |
| | 10.5.3 | 528.000 | 3 | 176.000 | 19.622 | 0.000 |
| | 10.5.4 | 314.667 | 3 | 104.889 | 13.111 | 0.000 |
| | 11.1 | 113.280 | 3 | 37.760 | 11.134 | 0.000 |
| Fe+Zn | 10.5.1 | 100.000 | 3 | 33.333 | 5.500 | 0.003 |
| | 10.5.3 | 229.333 | 3 | 76.444 | 18.549 | 0.000 |
| | 10.5.4 | 170.667 | 3 | 56.889 | 11.175 | 0.000 |
| | 11.1 | 144.000 | 3 | 48.000 | - | - |

RMSE: Error Sum of Squares F: Comparison Table Value of Sample Means df: Degrees of Freedom
MSE: Error Mean Squares Sig. (p): Significance Level in Comparison

In Demir 2000 variety, the highest disease severity was observed in the early and mid-late periods, depending on the application of increased fertilizer doses (Table 15). In the early period, $Fe_5$, $Fe_{20}$, $Zn_{7.5}$ and $Fe+Zn_{(5+7.5)}$ were found in applications (+71.40%, +7.12%, +28.55%, +28.55%) (Table 15 and 17). In the mid-late period, an increase in disease severity was observed in the application of $Fe_{10}$, $Fe_{20}$, $Zn_{30}$, and $Fe+Zn_{(5+7.5)}$ fertilizer doses (+9.52%, +14.29%, +14.29%, +4.76%) (Table 15 and 16).

Significant reductions in disease severity depending on the application of varying fertilizer doses which were determined most at the $Zn_{30}$ fertilizer dose in the early period (-35.73%) and the $Zn_{7.5}$ and $Zn_{15}$ fertilizer doses in the mid- late period (-21.70%, -9.52%). In the late period, increases were found in all fertilizer application doses when compared to plants without disease symptoms (Table 17).

**Table 15.** According to different phenological periods for mineral fertilizer applications *(Fe, Zn, Fe+Zn)* disease change rates (%) in Demir 2000 variety

| | Phenological Periods | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Demir 2000 | 25 May 2019 (10.5.1) | | 06 June 2019 (10.5.3) | | 15 June 2019 (10.5.4) | | 23 June 2019 (11.1.1) | | Mean | |
| Application | % DS | % Change | % DS | % Change | % DS | % Change | % DS | % Change | % DS | % Change |
| No Fertilizer (0) | 18.67 | 0.00 | 48.00 | 0.00 | 63.00 | 0.00 | 75.00 | 0.00 | 51.17 | 0.00 |
| Fe 5g/5 L | 32.00 | +71.40 | 48.00 | 0.00 | 60.00 | -4.76 | 84.00 | +12.00 | 56.00 | +9.44 |
| Fe 10g/5 L | 17.33 | +7.18 | 48.00 | 0.00 | 69.00 | +9.52 | 81.00 | +8.00 | 53.83 | +5.20 |
| Fe 20g/5 L | 20.00 | +7.12 | 48.00 | 0.00 | 72.00 | +14.29 | 84.00 | +12.00 | 56.00 | +9.44 |
| Zn 7.5g/5 L | 24.00 | +28.55 | 42.00 | -12.50 | 49.33 | -21.70 | 84.00 | +8.00 | 49.08 | +4.08 |
| Zn 15g/5 L | 18.67 | 0.00 | 42.00 | -12.50 | 57.00 | -9.52 | 81.00 | +12.00 | 50.42 | +1.47 |
| Zn 30g/5 L | 12.67 | -35.73 | 45.00 | -6.25 | 66.00 | +4.76 | 84.00 | +8.00 | 51.00 | +0.33 |
| Fe+Zn 5+7.5g/5 L | 24.00 | +28.55 | 42.00 | -12.50 | 66.00 | +4.76 | 84.00 | +12.00 | 54.00 | +5.53 |
| Fe+Zn 10+15g/5 L | 16.67 | -10.71 | 51.00 | +6.25 | 60.00 | -4.76 | 75.00 | 0.00 | 50.67 | +0.98 |
| Fe+Zn 20+30g/5 L | 17.33 | -7.18 | 48.00 | 0.00 | 72.00 | +14.29 | 84.00 | +8.00 | 55.33 | +8.13 |

**Table 16.** Multiple Comparison (ANOVA) variance analysis results of the effects of different mineral fertilizer applications (Fe, Zn, Fe+Zn) on disease reaction in Demir 2000 variety

| Periods (Feekes) | | 10.5.1 | 10.5.3 | 10.5.4 | 11.1.1 |
|---|---|---|---|---|---|
| Demir 2000 variety | | 25 May 2019 | 06 June 2019 | 15 June 2019 | 23 June 2019 |
| | | Disease Severity, % DS (Average ± SD) | | | |
| Doses | Rec. | (DAS-185) | (DAS-197) | (DAS-206) | (DAS-214) |
| 0 | 12 | 18.67±2.842 b | 48.00±1.279 a | 63.00±0.000 b | 75.00±1.279 a |
| Fe5 | 12 | 32.00±0.000 a | 48.00±2.558 a | 60.00±1.279 b | 84.00±1.279 b |
| Fe10 | 12 | 17.33±0.284 b | 48.00±2.558 a | 69.00±1.279 a | 81.00±0.000 b |
| Fe20 | 12 | 20.00±0.852 b | 48.00±2.558 a | 72.00±0.000 a | 84.00±1.279 b |
| Sig. | 48 | 0.590 / 1.000 | 1.000 | 0.103 | 1.000 / 0.237 |
| 0 | 12 | 18.67±2.842 a | 48.00±1.279 a | 63.00±0.000 a | 75.00±1.279 b |
| Zn7.5 | 12 | 24.00±0.000 a | 42.00±1.279 a | 49.33±1.989 c | 84.00±1.279 a |
| Zn15 | 12 | 18.67±1.137 a | 42.00±1.279 a | 57.00±1.279 b | 81.00±0.000 a |
| Zn30 | 12 | 12.67±0.000 b | 45.00±3.837 a | 66.00±1.279 a | 84.00±1.279 a |
| Sig. | 48 | 1.000 / 0.080 | 0.237 | 1.000 / 0.402 | 1.000 / 0.237 |
| 0 | 12 | 18.67±2.842 ab | 48.00±1.279 ab | 63.00±0.000 ab | 75.00±1.279 b |
| Fe+Zn5+7.5 | 12 | 24.00±0.000 a | 42.00±0.000 b | 66.00±1.279 b | 84.00±1279 a |
| Fe+Zn10+15 | 12 | 16.67±0.284 b | 51.00±1.279 a | 60.00±1.279 c | 75.00±1.279 b |
| Fe+Zn20+30 | 12 | 17.33±0.284 b | 48.00±2.558 ab | 72.00±0.000 a | 84.00±1.279 a |
| Sig. | 48 | 0.759 / 0.055 | 0.073 / 0.597 | 0.103 / 1.000 | 1.000 |

**Table 17.** According to phenological periods disease severity (%DS) evaluations at repetitive fertilizer application (Fe, Zn, Fe+Zn*)* doses Anova results in Demir 2000 variety

| Demir 2000 | Phenological Period (Feekes) | HKT | df | HKO | F | Sig. (P) |
|---|---|---|---|---|---|---|
| Fe | 10.5.1 | 1642.667 | 3 | 547.556 | 20.533 | 0.000 |
| | 10.5.3 | 0.000 | 3 | 0.000 | 0.000 | 1.000 |
| | 10.5.4 | 1080.000 | 3 | 360.000 | 36.667 | 0.000 |
| | 11.1 | 648.000 | 3 | 216.000 | 14.667 | 0.000 |
| Zn | 10.5.1 | 869.333 | 3 | 289.778 | 10.305 | 0.000 |
| | 10.5.3 | 297.000 | 3 | 99.000 | 1.681 | 0.185 |
| | 10.5.4 | 1948.000 | 3 | 649.333 | 29.927 | 0.000 |
| | 11.1 | 648.000 | 3 | 216.000 | 14.667 | 0.000 |
| Fe+Zn | 10.5.1 | 398.667 | 3 | 132.889 | 5.374 | 0.003 |
| | 10.5.3 | 513.000 | 3 | 171.000 | 4.976 | 0.005 |
| | 10.5.4 | 945.000 | 3 | 315.000 | 32.083 | 0.000 |
| | 11.1 | 972.000 | 3 | 324.000 | 16.500 | 0.000 |

RMSE: Error Sum of Squares F: Comparison Table Value of Sample Means df: Degrees of Freedom
MSE: Error Mean Squares Sig.(p): Significance Level in Comparison

In the Eser variety, in general, Iron (Fe) applications led to a decrease in disease severity in all phenological periods in the Bread Eser variety. Iron can reduce or moderate the effects of a variety of foliar diseases, including rust infections in wheat and bananas, to variable degrees (Graham and Webb, 1991). Applications of zinc (Zn) led to an increase in the early era, a drop in the middle period, and both an increase and a decline in the late period. Zn treatment, which has a direct toxic effect on pathogens rather than plant metabolism, can frequently lower the severity of disease (Graham and Webb, 1991).

Abd El-Hai et al. (2007), in laboratory and field experiments, stated that nutritional elements (Fe, Zn, Ca, Mn) were promising in controlling both rust and chocolate spot diseases in faba bean. Many traditionally used chemicals are insufficient to control brown spots and rust diseases (Harrison, 1988). In addition, these chemicals are used more limitedly due to the high cost of use and their negative environmental effects on microflora (Khaled et al., 1995).

Therefore, it has become important to develop alternative methods to control plant diseases in soybean. It has been reported that microelement applications from the leaf surface of some plants reduce plant diseases (Abd-El-Karem et al., 2004, El-Gamal et al., 2007). Micronutrients have been applied in many areas of plant production as plant growth stimulators (Scheuerll and Mahafee, 2006). The chlorophyll content was taken as an index for the degree of reduction in effective green areas. Rust diseases reduce photosynthetic activity in leaves and consequently lower yields, increase chlorophyll-a or chlorophyll-b concentrations of Fe and Zn microelements and the total content of leaves (Sinha et al., 1970; Rahhal, 1993). In addition, Abd El-Razek et al., (2012) reported that 4g/L micronutrient administration significantly increased chlorophyll-a compared to control. The same trend was found in chlorophyll b. However, the chlorophyll-b value was significantly lower than the chlorophyll- value. In a study on soybean in corn during the 2010-2011 and 2011-2012 development periods, they found that it reduced rust disease from 15.4% to 62.8% (Morsy and El. Morsy, 2013).

## Conclusions

In this study, it was observed that the area 60 cm above the root surface of the plant was affected more, and the application of Fe+Zn+Mn in the first season reduced the rust disease from 16.4% to 6.03% compared to the untreated (control) plant, and as a result, the disease decreased by 62.8%. In the same study, Zinc (Zn) application alone reduced the disease by 7.47%, and Fe+Mn application reduced 8.6%. During the 2011-2012 development period, the best results were obtained from zinc alone (5.1%), Manganese (7.6%) and Iron+Zinc+Manganese (7.9%). Application of Fe+Zn did not result in a decrease in the early period and did not result in a significant change in the middle and late periods. Bayraktar 2000 showed a decrease/increase in the early period, an increase in the early-mid period, an increase/decrease in the mid-late period, and an increase in the late period. While zinc (Zn) applications caused a decrease in the early period, they decreased/increased in the early-middle and mid-late periods, and increased in the late period. Fe+Zn applications, on the other hand, showed an increase/decrease in the early and mid-late period, and an increase in the severity of the disease in the early-middle and late periods. In Kenanbey, Fe applications caused an increase in disease severity in the early and early-mid periods, a decrease in the mid-late period, and an increase in the late period. The increase in Zn applications in the early period showed a decrease in the severity of the disease in all other periods. Fe+Zn applications increased in the early period and decreased in all other periods. In the Demir 2000, Fe applications increased/decreased in the early period, decreased/increased in the mid-late period, and increased in the late period. Zn applications increased/decreased in the early period, decreased/increased in the early-middle period, decreased/increased in the mid-late period, and increased in the late period. Fe+Zn applications increased/decreased in the early and mid- late periods, decreased/increased in the early-middle period, and increased in the late period. In terms of yield, the Bayraktar variety was observed as the least affected variety by disease severity, with yield increases, all other cultivars were significantly affected by disease severity, and yield decreases. In terms of reducing the severity of the disease with fertilizer applications, Iron (Fe) dose applications in the Eser variety and zinc (Zn) dose applications in the Kenanbey variety were both effective in reducing disease severity. Although Fe and Zn applications increased the disease severity in all phenological periods in the Bayraktar variety, they did not cause significant losses in yield. In Demir 2000 variety, Fe and Zn applications caused both an increase and a decrease in disease severity, and losses in yield were observed. When the phenological periods were compared, the change in disease severity was evaluated as the most observed variety after Kenanbey.

## Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that might apper to influence the work reported in this paper.

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## Author Contribution

MA: Idea/Hypothesis, Material, Method, Research, Data-Processing, Data-Analysis, Visualization, Executive/Consultant, Thesis Management, Original Drafting, Writing- Reviewing & Editing; KA: Data processing, Executive/Consultant, Writing-Reviewing & Editing. All authors have read and agreed to the published version of the manuscript.

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