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The effect of some micronutrients, bio-fertilizers and two fungicides on wheat common root rot disease and some growth parameters

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Abstract:

Common root rot caused by *Bipolaris sorokiniana* is one of the most important diseases of wheat worldwide. In this research, the effect of some micronutrients, bio-fertilizers, and fungicides including Zinc sulfate, Humic acid, Nitroxin, EM® (containing effective microorganisms), Probiotic (containing *Bacillus subtilis*), Pars Bacil (containing *Bacillus velezensis*), Trianum-P (containing *Trichoderma harzianum*), Bordeaux mixture and Rovral-TS® were evaluated for their ability to reduce disease severity index and improve some growth parameters in Heidari, as susceptible wheat cultivar. The experiments were conducted in a completely randomized design with four replicates and mean values were separated using the least significant difference (LSD) test. Based on the results, all tested treatments significantly reduced disease severity index and promoted some growth parameters compared with the positive (inoculated) control. Humic acid, Rovral-TS® and Trianum-P were among the most effective treatments in reducing disease severity up to 30.8, 31.2 and 32.0 percent, respectively, and Pars Bacil showed the least effect in reducing disease severity. Moreover, significant differences were observed on growth parameters compared to the positive control and appeared with the highest mean values. The application of such micronutrients and bio-fertilizers is recommended in localities where wheat common root rot disease is prevalent.

Keywords: Antifungal compounds, disease management, growth improvement, Wheat

Extended Abstract

Introduction

Bipolaris sorokiniana (Sacc.) Shoemaker was reported for the first time from barley in Khuzestan province, southwest of Iran (Altman et al., 1972) and later identified on wheat from Lorestan province (Darvishnia et al., 1998). Then, it was reported from other host plants including Agrostis tenuis Yasey, Festuca rubra L., Lolium perenne L., and Poa pratensis L. (Mirabolfathi & Ershad, 2006). Assessment of the mating type and fertility status of *B. sorokiniana* from five different provinces in Iran revealed high potential for sexual reproduction in populations obtained from Alborz, Kermanshah and West Azerbaijan provinces (Karamian et al., 2021). Results of a research on genetic diversity of *B. sorokiniana* revealed that SSR (Simple Sequence Repeat) was a reliable marker to determine the genetic diversity of the fungus (Zolfaghari et al., 2021). It was found that Marvdasht and Chamran cultivars were among the wheat cultivars with the highest yield in response to *B. sorokiniana* in temperate and warm regions of Fars province, respectively (Mansoori & Pazhoumand, 2005). Results of a research showed that Sablan, Zarin, and Niknejad cultivars were among of tolerant cultivars to *B. sorokiniana* (Samiee et al., 2008). Gholamaliyan *et al*. (2021) screened responses of 33 domestic and exotic wheat genotypes against *B. sorokiniana*, and reported Alvand as resistant cultivar (Gholamaliyan et al., 2021). Qalavand *et al*. (2023) reported the role of *GIP1*, *PIEP1*, and *LTP* genes in the development of wheat resistance to *B. sorokiniana (*Qalavand et al., 2023*)*. It has been specified that genotypes/cultivars of plants showed different reaction to a fungal pathogen with mild to severe symptoms due to different levels of resistance and/or susceptibility (Delaramifar et al., 2023; Shirzaei et al., 2025).

Reliance on chemical fungicides raises well-documented concerns such as non-target toxicity, disruption of beneficial microbial communities, and the risk of resistance development in pathogen populations. Therefore, it is necessary to adopt effective disease management strategies due to importance of wheat as a strategic product. The application of non chemical based methods have been considered in recent years (Delavari et al., 2026; Ganjali et al., 2024; Golzari et al., 2024; Irandegani et al., 2023; Iranmanesh et al., 2022; Jomeyazdian et al., 2024; Namazi et al., 2025, 2026; Narouei et al., 2021; Nouri et al., 2026; Rasteh et al., 2024). Micronutrients and bio-fertilizers are recommended as suitable alternatives which provide not only nutrients needed to enhance plant growth, but also protect plants against pathogens (Hamidi et al., 2014; Kumar Gupta et al., 2017).

Zinc sulfate is a source of supplying zinc with great effect on the yield and yield components of wheat. It is found that soil application of $ZnSO_4$ accumulated significantly higher dry matter in leaves, stem, and spikes (Chandrakumar et al., 2004). Nitroxin, a commercial nitrogen-fixing bio-fertilizer, containing *Azotobacter* and *Azospirillum* as plant growth promoting rhizobacteria (PGPR), showed beneficial effects on plant growth and development. Mohtadi et al. (2014) investigated some bio-fertilizers containing nitrogen-fixing bacteria, phosphate-dissolving bacteria, and chemical fertilizers on the qualitative and quantitative factors of wheat (Mohtadi et al., 2016). According to their results, the combined application of chemical and biological fertilizers gave better effects on wheat yield components. Bahari-Sarvi et al. (2013) found that Nitroxin was effective treatment for grain yield and leaf area of wheat (Bahari-Saravi et al., 2012). Valizadeh & Sabbagh (2014) revealed that Nitroxin reduced disease severity index caused by Pythium aphanidermatum (Edson) Fitzp. in cucumber seedlings, and increased the expression of Chitinase and Cupi4 resistance genes (Valizadeh & Sabbagh, 2015).

Humic acid is an important fertilizer that facilitates the absorption of nutrient elements, and prevents the accumulation of salinity in the soil (Khan et al., 2017). EM® includes effective microorganisms, including fungi (yeast),

photosynthesizing bacteria, and lactic acid bacteria. Compost fermented by EM® containing higher amounts of amino acids and polysaccharides directly absorbed by plants. Abu-Qaoud et al. (2021) reported that 100 ml L^{-1} of EM® was significantly effective on the length, and fresh/dry weight of wheat under salt tension (Abu-Qaoud et al., 2021).

Bacillus-based products including Probiotic and Pars Bacil contains *Bacillus subtilis* and *Bacillus velezensis*, respectively, which plays an important role in the bio-control of harmful microorganisms including fungi and bacteria. The effect of *B. subtilis* has been reported on colonization of wheat root and improvement of some growth factors including root length and dry weight as well as aerial organs (Khezri, 2017). The high efficacy of Pars Bacil has been proved on the management of important diseases, yield and yield components of cotton (Rasinataj et al., 2025).

Trianum-P is a commercial product containing *Trichoderma harzianum*, an effective bio-control agent with ability to inhibit the infection of pathogens. It has been proved that seed treatment and soil application of Trianum-P (30-40 gr for 1000 gr seed) showed high effect against *Fusarium* wilt of cucumber (Sarpeleh et al., 2013). Trichoderma-derived products including Trianum-P, Trichomix H-V, and Trichofang-S significantly reduced *Fusarium* wilt of melon (Khatib et al., 2017).

In the present study, the effect of Zinc sulfate, Nitroxin, Humic acid, EM®, Probiotic, Pars Bacil, and Trianum-P, as well as two fungicides including Rovral-TS® and Bordeaux mixture were evaluated on the wheat common root rot disease severity index caused by *B. sorokiniana* and some growth parameters. Management of disease with safe methods, increasing crop health, and reducing the usage of fungicides were among the most important goals of current research.

Materials and Methods

Preparation of fungal isolate

Bipolaris sorokiniana (strain B4 1656) was obtained from the Isfahan Agriculture and Natural Resources Research and Education Center, Isfahan, Iran. The fungus was previously isolated from infected wheat in Isfahan and used in previous researches (Gholamaliyan et al., 2021; Qalavand et al., 2023; Qalavand et al., 2022).

Experimental treatments

Micronutrients, bio-fertilizers and fungicides were prepared according to the instructions of the manufacturer. The experimental treatments were as follows: Zinc sulfate produced by Nobaharan Shimi Sepahan Company, Iran, as a seed coating before planting, Humic acid (BioHumAT-30) produced by Vatan Plast Azar Company, Iran, as a seed coating before planting, Nitroxin produced by Mehr Asia Biotechnology Company, Iran, containing nitrogen-fixing bacteria as a seed coating before planting, Probiotic produced by Tabiat-Gara Biotechnology Company, Iran, as a seed coating before planting, EM® produced by Agriplus Company, Iran, as a seed coating before planting, Pars Bacil produced by Royan Tisan Sabz Company, Iran, as a seed coating before planting, Trianum-P as a seed coating before planting, Bordeaux mixture produced by Sabzdaru Company, Iran, at a rate of 1:1000 (w/v) as a seed coating before planting and Rovral-TS® (52.5% WP) produced by Ariashimi Company, Iran, at a rate of 1:1000 (w/v) as a seed coating before planting.

Soil inoculation

A volume of 100 ml of *B. sorokiniana* spore suspension at a concentration of 5×10^6 spore/ml counted with a hemocytometer slide was added with every 100 gr sterile neutralized peat and oven-sterilized mixture of sand-peat moss in equal volume (1:1) in plastic pots. The inoculated substrate was kept for two weeks. Seeds of the Heidari cultivar known to be susceptible to common wheat root rot disease were used in all experiments. The soil in some pots was not inoculated with the fungus (negative controls) in order to compare the effects of treatments without the presence of the fungus with those of with fungus (positive controls). Pots were placed in a greenhouse at temperatures of 27/20 ± 2 °C (day/night) with 12 h of daylight (Mohtadi et al., 2016).

Disease severity index (DI)

Disease severity index was estimated according to the spread of rot reaching up to the first node of the stem, using a scale 1- 4, where 1 = clean: 0%, 2 = slight: 1–25%, 3 = moderate: 26–50% and 4= sever: more than 50% (Banu & Deverall, 1996). Experiments were carried out under greenhouse conditions with four replicates. Disease severity index (DI) was calculated using the following formula:

$$DI\ \% = \sum(ni \times xi) / N \times S \times 100$$

Where DI is: Disease severity index; ni: the number of plants in each treatment; xi: the severity of the disease in each treatment according to the scale; N: the total number of examined plants; S: the highest disease severity score according to the scale

Evaluation of some wheat growth parameters

Growth parameters including shoot and root length, root volume, leaf length, and fresh and dry weight of shoots and roots were evaluated using standard ruler (Stainless, ISO9002 certified) and digital scale (DM.3, China) in treatments containing micronutrients and bio-fertilizers and compared with the controls.

Statistical analysis

The experiments were carried out in a completely randomized design with four replicates. SPSS 24 was used for analysis of data. The mean values were separated using the least significant difference (LSD) test at p>0.05. In all figures, the mean values that have at least one letter in common are not significantly different at p>0.05 of the LSD test.

Results

Micronutrients, bio-fertilizers, and fungicides used in the current research significantly reduced disease severity index of *B. sorokiniana* and promoted some growth parameters of wheat compared with the positive control. The effect of each treatment is discussed separately. The analysis of variance of the data and the mean value comparison of different treatments are presented in Table 1 and Table 2, respectively. A significant difference (p>0.05) in disease severity index was observed compared to the positive control. The mean value comparison out of four replicates showed that Humic acid (30.8), Trianum-P (32.0), and Rovral-TS® (31.2) were among the most effective treatments in reducing disease severity index and classified in the same statistical group (Fig. 1).

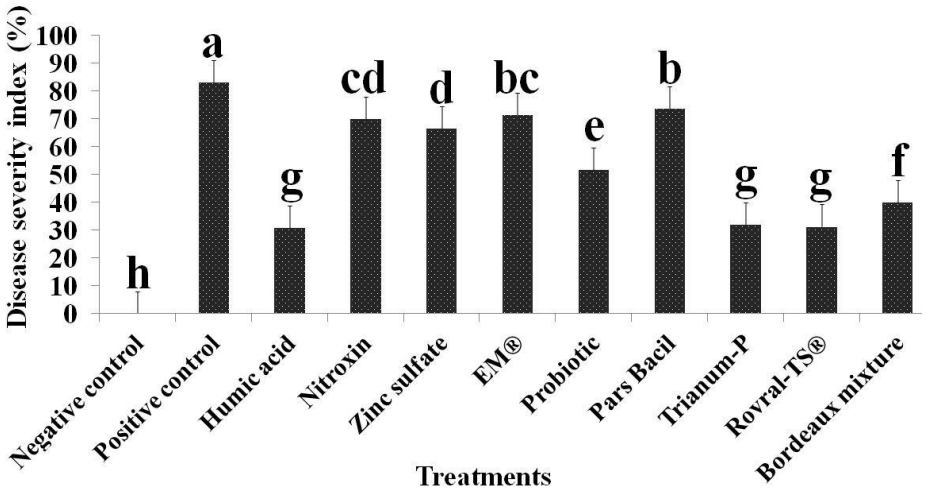

Fig 1. Mean of four replicates of disease severity index (%) caused by *Bipolaris sorokiniana* on wheat treated with micronutrients, bio-fertilizers, and fungicides.

Table 1. Analysis of variance of the investigated parameters of wheat under the influence of micronutrients, bio-fertilizers and fungicides.

Source of variation	Degree of Freedom	Disease severity index	Leaf length	Root volume	Root length	Root fresh weight	Root dry weight	Shoot length	Shoot fresh weight	Shoot dry weight
Treatment	10	1.12913^{**}	43.67^{**}	6.738^{**}	37.36^{**}	6.484^{**}	0.0812^{**}	55.62^{**}	0.0414^{**}	1.774^{**}
Repeat	3	2.8^{ns}	16.80^{ns}	1.058^{ns}	12.69^{ns}	2.644^{**}	0.0094^{**}	8.91^{ns}	0.0014^{ns}	0.469^{**}
Treatment × Repeat	30	2.8^{ns}	16.70^{*}	0.411^{ns}	7.68^{ns}	0.595^{**}	0.0070^{**}	4.68^{ns}	0.0024^{ns}	0.114^{ns}
Error	176	33.00	6.11	0.482	6.11	0.109	0.0013	6.52	0.0020	0.112
Coefficient of variation (CV %)	-	11.5	20.4	24.9	21.9	13.9	13.9	8.9	14.6	19.9

*significant at 5% (p>0.05), **significant at 1% (p>0.01), ^{ns} non-significant.

Table 2. Mean value comparison of different treatments using LSD test.

Factors Treatments	Disease severity index (%)	Leaf length (cm)	Root volume ($cm^{3)}$	Root length (cm)	Root fresh weight (gr)	Root dry weight (mg)	Shoot length (cm)	Shoot fresh weight (gr)	Shoot dry weight (mg)
Non inoculated (negative) control	0.0^{h}	16.4^{abcd}	3.40^{a}	12.7^{a}	2.99^{b}	290^{c}	28.6^{bcd}	3.28^{bc}	193^{b}
Inoculated (positive) control	83.2^{a}	14.8^{cde}	1.52^{d}	7.6^{c}	1.34^{e}	139^{h}	28.2^{cd}	1.96^{e}	107^{f}
Humic acid	30.8^{g}	18.0^{a}	2.68^{bc}	11.2^{ab}	2.16^{d}	274^{cd}	29.8^{ab}	2.91^{d}	159^{cde}
Nitroxin	70.0^{cd}	14.7^{de}	3.65^{a}	12.2^{ab}	3.30^{a}	382^{a}	26.3^{e}	3.32^{b}	175^{bc}
Zinc sulfate	66.6^{d}	14.6^{de}	2.92^{b}	10.9^{b}	2.67^{c}	262^{de}	29.7^{abc}	3.20^{bc}	166^{cde}
EM®	71.5^{bc}	15.9^{bcd}	2.52^{bc}	11.3^{ab}	2.19^{d}	263^{de}	26.0^{e}	3.01^{cd}	152^{de}
Probiotic	51.8^{e}	13.6^{e}	2.88^{bc}	11.2^{ab}	2.22^{d}	251^{ef}	28.4^{bcd}	3.26^{bc}	174^{bc}
Pars Bacil	73.8^{b}	16.9^{ab}	2.45^{c}	10.7^{b}	2.11^{d}	237^{f}	27.1^{de}	2.89^{d}	149^{e}
Trianum-P	32.0^{g}	18.0^{a}	2.60^{bc}	12.0^{ab}	2.12^{d}	231^{f}	30.2^{a}	3.06^{bcd}	174^{bc}
Rovral-TS®	31.2^{g}	17.2^{ab}	2.63^{bc}	12.1^{ab}	2.86^{c}	206^{g}	31.0^{a}	2.92^{d}	171^{cd}
Bordeaux mixture	40.0^{f}	16.9^{ab}	3.40^{a}	12.0^{ab}	3.12^{ab}	334^{b}	30.2^{a}	3.85^{a}	228^{a}

A significant difference (p>0.05) in leaf length were observed in treatments including Humic acid (18.0), Trianum-P (18.0), Rovral-TS® (17.2), Pars Bacil (16.9) and Bordeaux mixture (16.9). These treatments were placed in the same statistical group. Probiotic (13.6) appeared with the lowest mean value. The remaining treatments had no a significant difference compared to the positive control (Fig. 2).

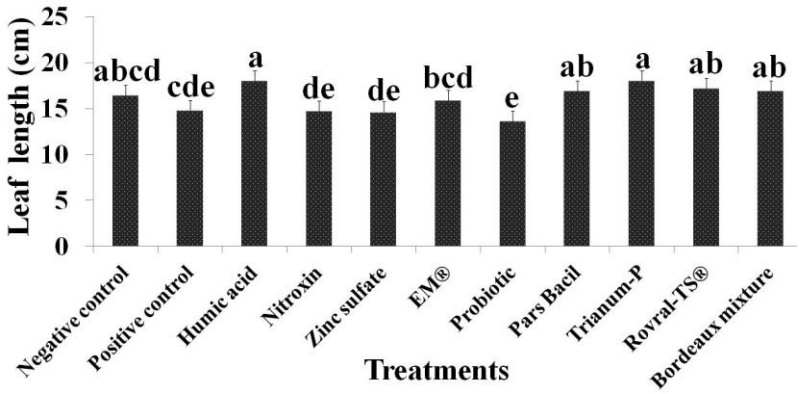

Fig 2. Mean of four replicates of different treatments on leaf length (cm).

A significant difference (p>0.05) in root volume were observed in all treatments compared to the positive control. Nitroxin (3.65) and Bordeaux mixture (3.4) showed the highest mean values. Other treatments were not significantly different (Fig. 3).

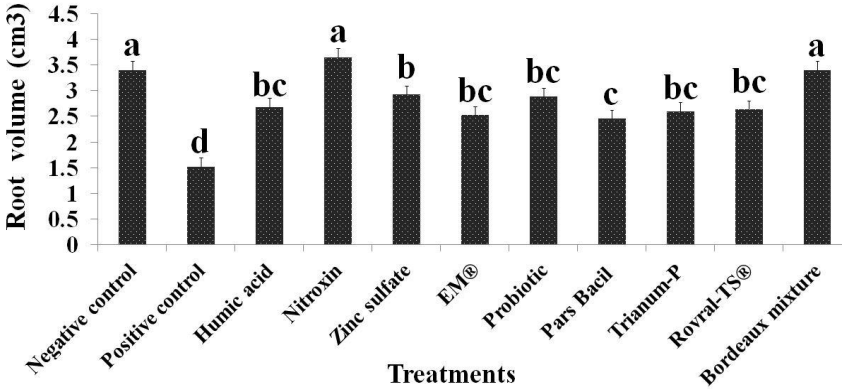

Fig 3. Mean of four replicates of different treatments on root volume (cm^3).

A significant difference (p>0.05) in root length were observed in all treatments compared to the positive control. The remaining treatments were belonged to the same statistical group (Fig. 4).

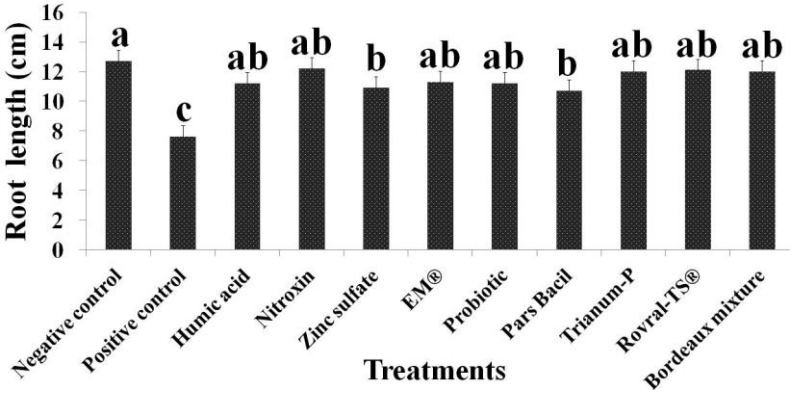

Fig 4. Mean of four replicates of different treatments on root length (cm).

A significant difference (p>0.05) in root fresh weight were observed in all treatments compared to the positive control. Nitroxin (3.30) and Bordeaux mixture (3.12) showed the highest mean values, followed by Rovral-TS® (2.68) and Zinc sulfate (2.67). Probiotic, EM®, Humic acid, Trianum-P, and Pars Bacil were classified in the same statistical group (Fig. 5).

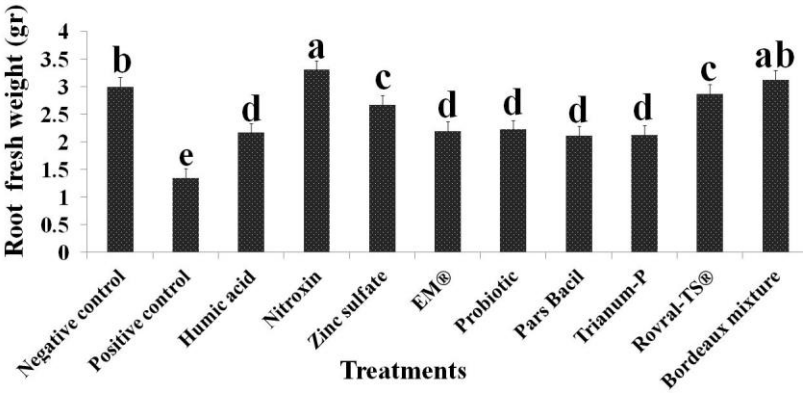

Fig 5. Mean of four replicates of different treatments on root fresh weight (gr).

A significant difference (p>0.05) in root dry weight were observed in all treatments compared to the positive control. Nitroxin (382) showed the highest mean value, followed by Bordeaux mixture (334). Humic acid, Zinc sulfate, and EM® were placed in the same statistical group. Rovral-TS® showed the lowest mean value (Fig. 6).

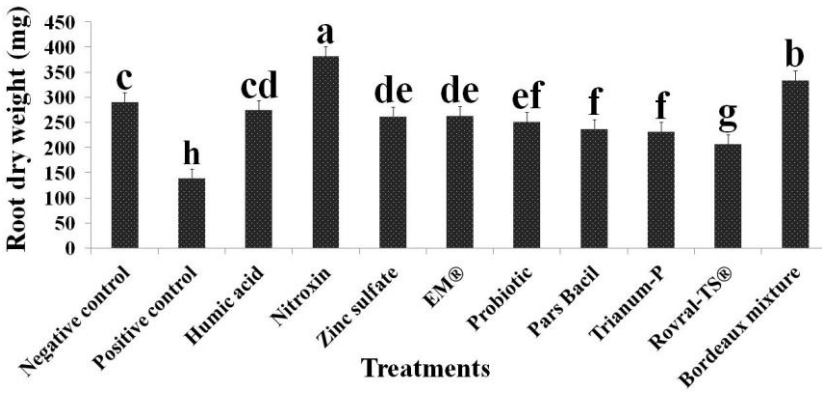

Fig 6. Mean of four replicates of different treatments on root dry weight (mg).

A significant difference (p>0.05) in shoot length were observed in four treatments compared to the positive control. Rovral-TS® (31.0), Trianum-P (30.2), Bordeaux mixture (30.2), Humic acid (29.8) and Zinc sulfate (29.7) were not significantly different. Nitroxin (26.3) and EM® (26.0) appeared with the lowest mean values (Fig.7).

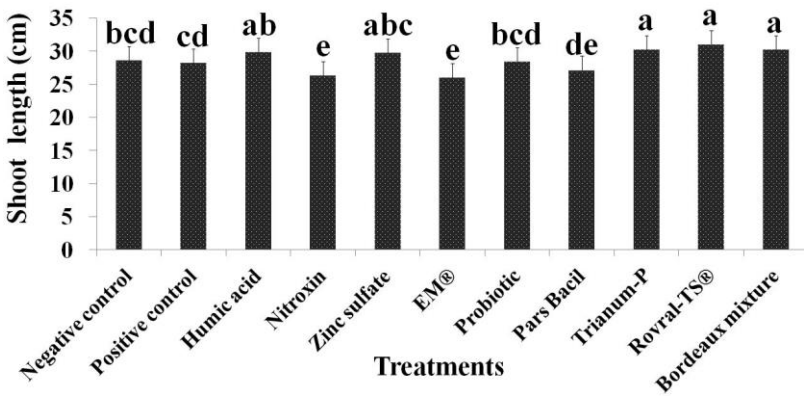

Fig 7. Mean of four replicates of different treatments on shoot length (cm).

A significant difference (p>0.05) in shoot fresh weight were observed in all treatments compared to the positive control. Bordeaux mixture (3.85) showed the highest mean value. Nitroxin (3.31), Probiotic (3.25), Zinc sulfate (3.20) and Trianum-P (3.06) were not significantly different. EM®, Humic acid, Rovral-TS® and Pars Bacil were belonged to the same statistical group (Fig. 8).

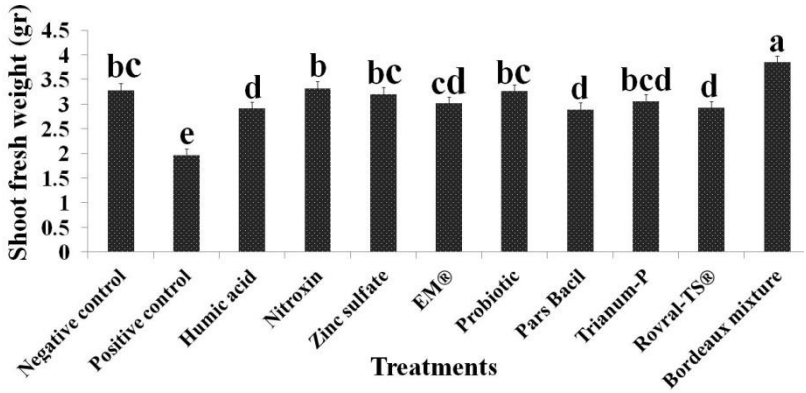

Fig 8. Mean of four replicates of different treatments on shoot fresh weight (gr).

A significant difference (p>0.05) in shoot dry weight were observed in all treatments compared to the positive control. Bordeaux mixture (228) showed the highest mean value, followed by Nitroxin (175), Probiotic (174), and Trianum-P (174), Rovral-TS® (171), Zinc sulfate (166) and Humic acid (159) which were placed in the same statistical

group. Pars Bacil (149) showed the lowest mean value (Fig. 9).

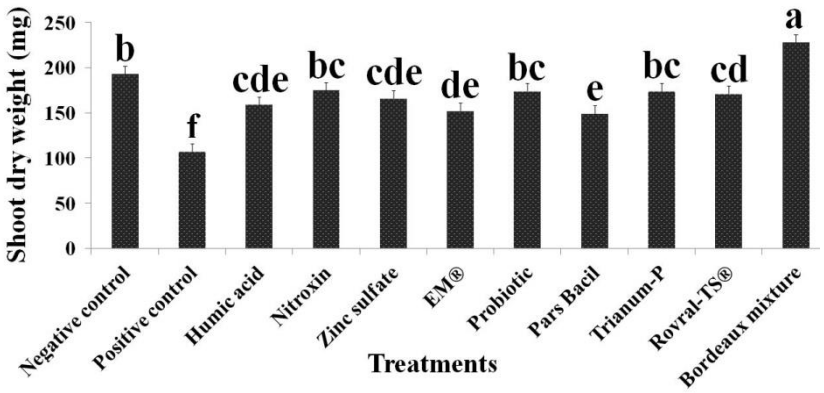

Fig 9. Mean of four replicates of different treatments on shoot dry weight (mg).

Correlation analysis among the investigated treatments revealed a negative and significant relationship between disease severity index and growth parameters (Table 3).

Table 3. Correlation between disease severity index and growth parameters

	Disease severity index	Shoot length	Root length	Leaf length	Root volume	Shoot fresh weight	Root fresh weight	Shoot dry weight	Root dry weight
Disease severity index	1								
Shoot length	-0.284**	1							
Root length	-0.344**	-0.030	1						
Leaf length	-0.206**	0.167*	-0.038	1					
Root volume	-0.282**	0.068	0.406**	-0.037	1				
Shoot dry weight	-0.393**	0.181**	0.433**	-0.043	0.705**	1			
Root fresh weight	-0.303**	0.055	0.398**	-0.039	0.711**	0.634**	1		
Shoot fresh weight	-0.289**	0.115	0.385**	0.023	0.703**	0.720**	0.580**	1	
Root dry weight	-0.148*	-0.143*	0.327**	-0.035	0.629**	0.520**	0.757**	0.607**	1

**significant at 1% (p>0.01), *significant at 5% (p>0.05)

Discussion

The results demonstrated notable potential of all tested treatments in reducing disease severity index of *B. sorokiniana* on Heidari, a wheat cultivar susceptible to common root rot. Certain treatments exhibited lower or non-significantly different mean values in some growth parameters compared to the positive control. For instance, Nitroxin and EM® resulted in the lowest shoot length mean values, while Probiotic produced the lowest leaf length mean value. Similarly, treatments such as Probiotic, Pars Bacil, and Zinc sulfate in the shoot length, as well as EM®, Nitroxin, and Zinc sulfate in the leaf length, did not differ significantly from the positive control. A plausible explanation is that above mentioned treatments did not sufficiently improve resource acquisition. Reviews of bio-fertilizer highlight that inconsistent product quality, erratic microbial survival, and lack of effective colonization are common causes of such null effects (Rai et al., 2023). Many micronutrients and bio-fertilizers require precise timing, appropriate dosage, and compatible environmental conditions to be beneficial. Failure to meet these requirements, for example, applying when soil moisture, temperature, or root exudates composition are unfavorable, can prevent establishment or activity of the beneficial

organisms and thus nullify any growth-promoting effects. Empirical studies and reviews emphasize the importance of application timing and environmental matching for reliable performance (Abou Jaoudé et al., 2025). Some bio-fertilizers or micronutrients can transiently disrupt plant physiology thereby reduce growth in the short term, and phytotoxic responses at inappropriate concentrations. Such transient negative effects would explain lower mean values in some growth parameters compared with the infected control (Orlina et al., 2023). Under infection, plants balance resource allocation between growth and defense. Certain treatments may prime defense but at the cost of immediate growth or conversely fail to prime defense while imposing additional nutrient demands (Ammar et al., 2023).

The finding that Nitroxin and EM® produced the lowest shoot-length mean values may reflect the well-documented variability in the field efficacy of complex microbial inoculants. Some review studies report that EM® and other mixed microbial consortia sometimes fail to increase or even have no effect on crop growth under certain field conditions, likely because of inconsistent establishment, competition with native microbiome, or unsuitable formulation for the target crop (Mayer et al., 2010).

Similarly, the reduced leaf length observed with the Probiotic treatment is consistent with the variable responses often reported for probiotic bacteria, while many strains promote growth under optimal colonization and environmental conditions, their effects on specific morphological traits can be neutral or negative when colonization or nutrient status are suboptimal (Jiang et al., 2024). Zinc (Zn) is a recognized micronutrient for enzymatic and signaling roles in plant defense, but its positive effects are dose-dependent. Low to adequate Zn can enhance antioxidant and defense enzyme activity, while inappropriate doses or interactions with soil chemistry can limit uptake or cause imbalances. Reviews on Zn and plant immunity provide a mechanistic basis for why $ZnSO_4$ sometimes fails to improve, or may not differ from infected controls (Cabot et al., 2019). Additionally, some treatments may temporarily disrupt plant metabolic balance or cause mild toxicity (Orlina et al., 2023). Consequently, these inputs did not enhance the growth-related processes under pathogen pressure.

The higher mean value of Humic acid in suppressing root rot of wheat can be attributed to its synergistic mode of action. Humic substances are known to act as elicitors of plant immunity, which can induce the activation of defense-related enzymes such as peroxidase (PO), polyphenol oxidase (PPO), and phenylalanine ammonia-lyase (PAL). Increased PAL activity enhances the phenylpropanoid pathway, leading to the accumulation of lignin, phytoalexins, phenolic compounds, and structural barriers that restrict colonization of *B. sorokiniana* (Silva et al., 2023; Silva et al., 2025). Humic acid improves root development by stimulating root elongation, lateral root formation, and nutrient uptake (Faria de Souza et al., 2025). A more vigorous root system reduces disease impact by increasing plant tolerance and minimizing the extent of necrotic lesions. Additionally, humic acid modify rhizosphere pH, cation exchange capacity, and nutrient availability, creating conditions less favorable for pathogen proliferation. This indirectly suppresses *pathogens* by promoting microbial activity and enhancing resource competition (Costa et al., 2023).

Trianum-P showed a high mean value in reducing disease severity index compared to Probiotic and Pars Bacil. *T. harzianum* in commercial product Trianum-P can produces a wide spectrum of antifungal secondary metabolites which inhibit spore germination, hyphal elongation, and cellular metabolism in *B. sorokiniana*. It has been reported that combined application of *T. harzianum* and methyl jasmonate enhanced indole acetic acid (IAA) production in the rhizosphere of wheat which in turn helps in plant growth and development. Further, the combined application found to enhance the activities of defense related enzymes against *B. sorokiniana*, which increase the resistance to disease by stimulating enzymatic activities and the accumulation of phenolic compounds (Singh et al., 2019). Increase in

production of oxidative defense-related enzymes in wheat against *B. sorokiniana*, is also reported by Qalavand *et al*. (2022) (Qalavand et al., 2022).

Probiotic showed higher mean value in reducing disease severity index compare to Pars Bacil, and higher mean values in shoot dry/fresh weight and leaf length. This finding was in agreement with Khezri (2017) (Khezri, 2017), who reported that Probiotic increased the wheat root length and dry weight. Pars Bacil showed moderate mean values almost in all treatments, except for shoot fresh weight, where it had the lowest mean value. However, leaf length showed a higher mean value compared to the Probiotic. Probiotic contains *B. subtilis* which produce antibiotics, lytic enzymes, siderophores and volatile organic compounds that inhibit spore germination and mycelial growth of *B. sorokiniana*. It has been shown that *B. subtilis* markedly restrict conidial germination and lesion expansion (Villa-Rodríguez et al., 2019). Nitroxin containing *Azotobacter* and *Azospirillum*, can promote plant growth and suppress diseases. Importance of Nitroxin in wheat yield and yield components were also reported in previous studies (Bahari-Saravi et al., 2012; Bakhshaie et al., 2014). Disease suppression can occur through induced systemic resistance (ISR) via Jasmonic acid/Salicylic acid pathways, enhancing tolerance to pathogens as well as improving nutritional status. Pathogens are differentially sensitive to the resistances activated by each of these signaling pathways (Van Loon, 2007).

In current study EM® showed a lower mean values in most parameters compared to the Nitroxin, Zinc sulfate, and Humic acid resulted in higher mean values than EM® in reducing disease severity index, and in shoot parameters including length, fresh/dry weight, as well as root parameters such as volume and dry weight. EM® contains bioactive substances which contributed to antioxidant activity against fungal pathogens (Saleh et al., 2024), and showed variable but often positive effects against some leaf/root fungal disease of wheat (Boligłowa & Gleń, 2008).

Bacillus and *Trichoderma* provided strong antagonistic activity that limited spore germination and mycelial growth, while Humic acid and Nitroxin enhanced host physiology by priming defense pathways, improving nutrient uptake, and hormonal balance. Probiotic and EM® contributed indirectly by shifting the soil microbiome toward beneficial communities that compete with or suppress pathogens.

The efficacy of Rovral-TS® and Bordeaux mixture as seed treatment was evaluated for the first time in this study. Rovral-TS® showed a higher mean value than Bordeaux mixture in reducing disease severity index. However, Bordeaux mixture resulted in higher mean values in several root parameters including volume, fresh/dry weight, and shoot fresh/dry weight. Fungicides can inhibit spore germination, mycelial growth and sporulation of the fungus and often produce rapid and reliable disease control in short-term trials, but their environmental risks and the potential for resistance underscore the importance of transitioning toward preventive, eco-friendly-based management.

The correlation between disease severity index and the growth parameters was negative and significant, indicating that increased disease severity index can severely reduce plant growth parameters. Such a pattern aligns well with understanding, as disease is known to interfere with key metabolic processes, including respiration, photosynthesis, and nutrient uptake. The statistical significance of this correlation suggests that as disease severity increases, a larger proportion of metabolic resources diverted from growth-related processes toward defense responses, leading to measurable declines in growth parameters. The consistency of our findings with reports from similar studies indicates that micronutrients and bio-fertilizers can provide durable and environmentally compatible suppression of wheat common root rot due to direct antagonism and host defense stimulation.

Conflict of Interest

There is no conflict of interest in conducting the present study.

Ethical Considerations

All ethical principles and standards were fully observed in the conduct of this research.

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چکیده

بیماری پوسیدگی معمولی ریشه ناشی از قارچ *Bipolaris sorokiniana* یکی از مهم‌ترین بیماری‌های گندم در سراسر جهان است. در این تحقیق، تأثیر برخی از ترکیبات ریزمغذی و کودهای زیستی شامل سولفات روی، هیومیک اسید، نیتروکسین، EM® (حاوی میکروارگانیسم‌های مؤثر)، پروبیوتیک (حاوی *Bacillus subtilis*)، پارس باسیل (حاوی *Bacillus velezensis*)، تریانوم-پی (حاوی *Trichoderma harzianum*) و دو قارچکش شامل مخلوط بردو و Rovral-TS® بر شدت بیماری *B. sorokiniana* و بهبود برخی از فاکتورهای رشد رقم حساس گندم Heidari ارزیابی شدند. آزمایش‌ها در قالب طرح کاملاً تصادفی با چهار تکرار انجام شد و میانگین‌ها با آزمون حداقل تفاوت معنی‌دار (LSD) تفکیک شدند. بر اساس نتایج، ترکیبات ریزمغذی، کودهای زیستی و قارچکش‌ها به طور قابل توجهی شدت بیماری را کاهش داده و برخی از فاکتورهای رشد را در مقایسه با شاهد مثبت (تلقیح شده) بهبود بخشیدند. هیومیک اسید، Rovral-TS® و تریانوم-پی در میان موثرترین تیمارها در کاهش شدت بیماری به ترتیب تا ۳۰/۸، ۳۱/۲ و ۳۲/۰ درصد بودند و پارس باسیل کمترین تاثیر در کاهش شدت بیماری را نشان داد. علاوه بر این تفاوت معنادار در اغلب فاکتورهای رشد در مقایسه با شاهد مثبت (تلقیح شده) مشاهده شد و با مقادیر میانگین بالاتر ظاهر شدند. بنابراین استفاده از این ترکیبات ریزمغذی و کودهای زیستی در مناطقی که بیماری پوسیدگی معمولی ریشه گندم شایع است، توصیه می‌شود.

کلیدواژگان: *ترکیبات ضد قارچ، مدیریت بیماری، بهبود رشد، گندم*

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