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Proceeding Paper

The Effects of The Interaction Between Bacterial Inoculants and Mineral Fertilizers on Spring Barley Yield and Soil Properties

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Abstract: The hypothesis of this study was that complex mineral fertilizers ($N_5P_{20.5}K_{36}$) coated with a bacterial inoculant (*Paenibacillus azotofixans, Bacillus megaterium, Bacillus mucilaginosus, Bacillus mycoides*) have a positive effect on the agrochemical composition of the soil and on the yield of spring barley. Experimental studies were carried out three years on sandy loam soil in four different treatments: no $N_5P_{20.5}K_{36}$ (control), 300 kg ha^{-1} $N_5P_{20.5}K_{36}$ (Tr-1), 150 kg ha^{-1} $N_5P_{20.5}K_{36}$ coated with a bacterial inoculant (Tr-2) and 300 kg ha^{-1} $N_5P_{20.5}K_{36}$ coated with a bacterial inoculant (Tr-3). Based on research results, we found that bacterial inoculant-enriched fertilizer increases the yield of barley grain without exhausting the soil.

Keywords: bacteria; soil; potassium; phosphorus; barley yield.

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1. Introduction

From an environmental and human health point of view, biofertilizers are used as a better alternative to chemical fertilizers. Microorganisms, including bacteria and cyanobacteria, are present in biofertilizers sprinkled on plant surfaces, seeds, or soil cover the rhizospheres, or internal spaces, of plants [1,2,3]. Biswas et al. [4] provides a recommendation for the use of biological inoculants with mineral fertilizers. Microbial biofertilizers are cost-effective and cheaper than conventional techniques. They provide 25–30% of the chemical fertilizer equivalent of nitrogen. They increase phosphorus and potassium content in soil, increase water absorption and keep soil biologically active. In soils cropped with legumes, the application of arbuscular mycorrhizal fungi inoculants tremendously improves growth and yields [5,6]. There is currently a lack of knowledge about the effects of biologically enriched, complex mineral fertilizers on soil and spring barley yield. Therefore, the aim of the study was to determine the influence of bacteria-inoculated complex mineral fertilizer on the soil properties and yield of spring barley.

2. Materials and Methods

Experimental field research was carried out in 2020–2022 in the region of Lithuania characterized by Endoeutric Albeluvisol (Orthieutric Albeluvisol). Experimental studies were carried out on sandy loam soil in four different treatments: no ($N_5P_{20.5}K_{36}$) (control), 300 kg ha^{-1} $N_5P_{20.5}K_{36}$ (Tr-1), 150 kg ha^{-1} ($N_5P_{20.5}K_{36}$) coated with a bacterial inoculant (Tr-2), and 300 kg ha^{-1} ($N_5P_{20.5}K_{36}$) coated with a bacterial inoculant (Tr-3). The arrangement of the experimental treatment plots is presented in Figure 1. The complex mineral fertilizers were coated with a bacterial inoculant (500 g ha^{-1}). The bacterial inoculant (*Paenibacillus azotofixans, Bacillus megaterium, Bacillus mucilaginosus, and Bacillus mycoides*) provided by JSC Nando, Lithuania, was used in equal concentrations (1×10^9 cfu g^{-1}). Nitrogen fertilizer was applied to the crops at the end of tillering (BBCH 25–30). A rate of 68.8 kg N ha^{-1} of ammonium nitrate (NH_4NO_3; $N_{34.4}$) was applied. During the experimental studies, the spring barley Hordeum vulgare L. (cv. Iron) seed rate was 4.0–4.5 million units ha^{-1}.

Soil samples collected from each experimental plot (from 15 locations) (Figure 1) were mixed and analyzed at the Agrochemical Research Laboratory. The amount of available phosphorus and potassium (mg kg^{-1}) was determined by the Egner-Riehm-Domingo (A-L) method (LVP D-07:2016).

Ten random plant samples were taken from each plot (Figure 1), for a total of 30 samples per treatment. The samples were threshed with a stationary Wintersteiger LD 350 laboratory threshing bench (Wintersteiger GmbH, Austria). The weight of the threshed grains (g) was then determined.

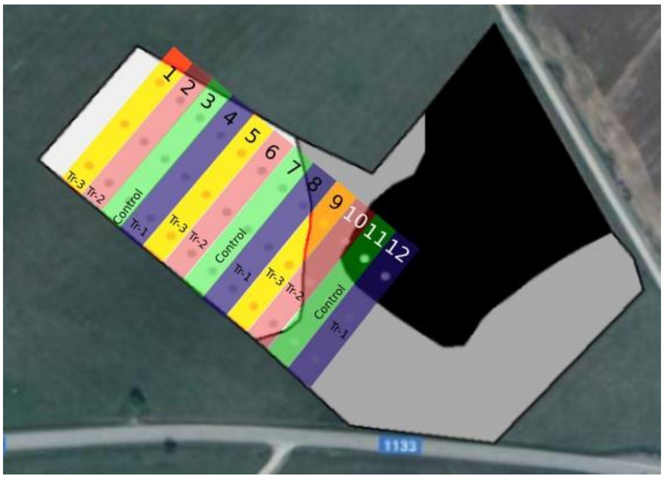

Figure 1. Arrangement of experimental plots.

A probability level of 0.05 was used as the criterion for tests of significance throughout the data analysis.

3. Results and Discussion

3.1. Soil properties

After three years of experimental studies of soil properties in spring and autumn, in the third year in spring, a decrease in soluble potassium (K_2O) of 1.5 mg kg^{-1} in the control, and an increase in other treatments were observed (Figure 2). In both spring and autumn, the highest increase in potassium (K_2O) was observed in Tr-3 (17.8 mg kg^{-1} and 14.5 mg kg^{-1}, respectively). Comparing the change of soluble phosphorus (P_2O_5) in the soil, the highest increase of Tr-3 (8.5 mg kg^{-1}) was found in spring, and the highest increase of Tr-2 (15.3 mg kg^{-1}) was found in autumn. The study by Zhao et al. [7] showed that using microbial inoculants during the 147 days research period, the concentration of plant-available potassium in the soil increased by 28.1%, and the amount of plant-available phosphorus increased by 38.1%. Li et al. [8] also reported that using bacterial inoculants in three different crops (oats, alfalfa, and cucumber) increased the amount of plant-available phosphorus in the soil by 38.1–52.0%, while the amount of soluble potassium increased by 3.01–26.81%.

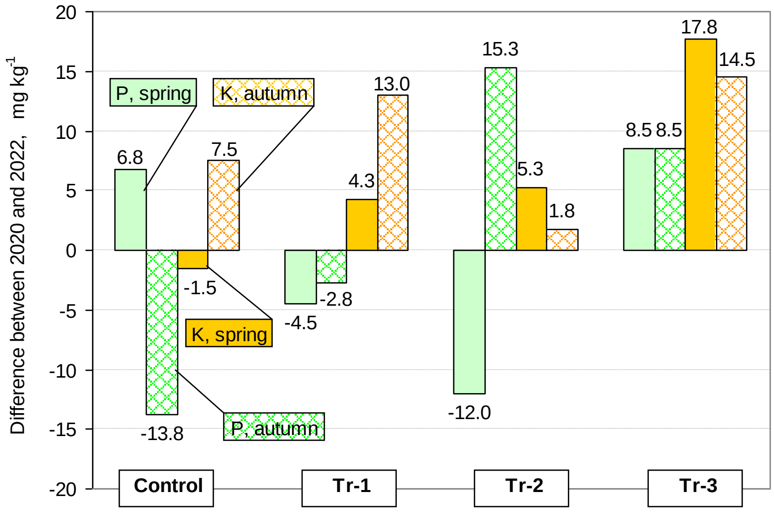

Figure 2. The effects of different treatments on changes in soil properties.

3.2. Barley grain yield

In the first year of the study, the spring barley grain yield varied from 5.21 t ha^{-1} to 6.40 t ha^{-1}; in the second year it varied from 2.29 t ha^{-1} to 3.82 t ha^{-1}; and in the third year – from 2.31 t ha^{-1} to 5.43 t ha^{-1} (Figure 3). In all research years, the lowest grain yield was in the control and the highest in Tr-3. The increase in potassium and phosphorus content in the soil may have influenced the yield increase in Tr-3. In the third year of the study, significant effects of the use of the biological preparation were observed, as the grain yield of Tr-3 (300 kg ha^{-1} fertilizer rate, biologically enriched) significantly increased compared to Tr-1 (300 kg ha^{-1} fertilizer rate, not biologically enriched).

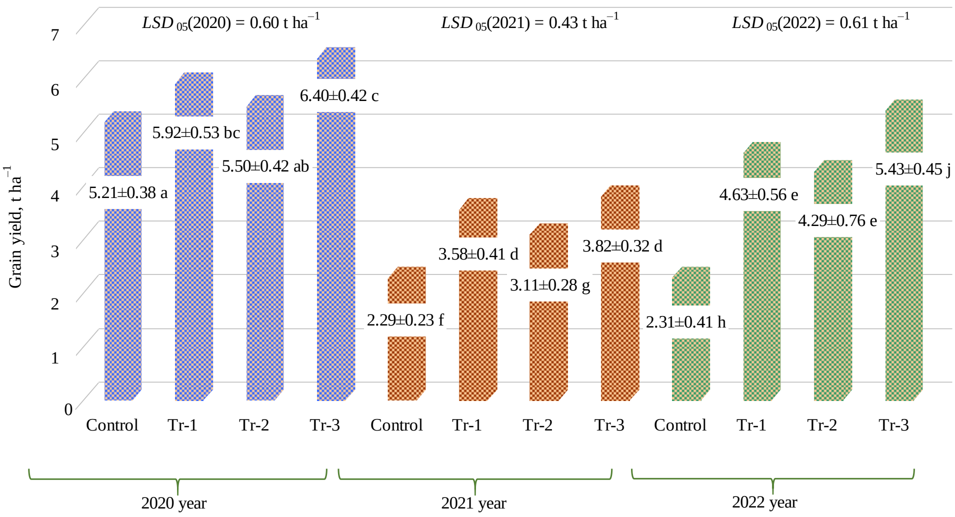

Figure 3. The effects of different treatments on grain yield.

Ahmad et al. [9] conducted research on growing wheat and fertilizing it with mineral fertilizers with bacterial impregnant and with fertilizer without impregnant, results of the research showed that the yield increased by 20% due to greater availability of nutrients. Also reports that it is possible to increase rice yields by 17.73% by incorporating bacterial inoculants into fertilization technology [10].

4. Conclusion

The results showed that in all the years of the research, Tr-3 spring barley yields increased by 8%, 7%, and 17%, respectively, compared to Tr-1. This indicates that biological enrichment with fertilizers increases the yield without increasing the fertilizer rate. This was due to the increase of potassium and phosphorus in the soil and the ability of bacterial inoculants to convert insoluble phosphorus and potassium compounds into soluble ones.

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