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REVIEW ARTICLE

EFFECT OF BIOSTIMULANTS ON WHEAT YIELD AND GRAIN QUALITY

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ABSTRACT

Wheat (*Triticum aestivum* L.) is one of the most important agricultural crops worldwide, serving as both a staple food and a primary source of income for millions. Its grain quality is influenced by genetic, environmental, and management related factors, with test weight (hectoliter weight) being a key parameter for commercial classification. This study aimed to evaluate the effect of the biostimulant Penergetic, applied in different forms and dosages, on wheat yield and grain quality. The field experiment was conducted in Santa Maria, Rio Grande do Sul, Brazil, using the ORS Soberano cultivar in a randomized block design with six treatments and eight replications. Treatments involving the combined application of the biostimulant in both liquid and solid formulations resulted in improved foliar health, indicating reduced biotic stress and enhanced biological balance in the soil. Consequently, significant increases in both grain yield and quality were observed, particularly in the treatment with the highest dosage, which achieved a test weight exceeding 80 kg.hL^{-1}. The biostimulant effect of the commercial Penergetic product contributed to enhanced enzyme activity in the soil, improved plant nutrient uptake, better foliar health, and overall vegetative development. The findings indicate that biostimulants based on Penergetic Technology significantly increase wheat yield and grain quality, with the most pronounced benefits observed under the combined application of both liquid and solid formulations at the highest tested dosage. These results emphasise the essential role of soil biological fertility in determining wheat crop performance.

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INTRODUCTION

Wheat cultivation represents one of the most important agricultural commodities of global relevance, playing a vital role in food security and the global economy. Wheat is a significant source of carbohydrates, proteins, and other essential nutrients, forming a dietary staple for billions of people across various regions of the world (Ulukan, 2024; Voučko *et al.,* 2025). Wheat grains have widespread applications in the food industry, particularly in the production of bread, pasta, and other staple food products consumed by diverse populations across cultures and traditions (Bentley *et al*., 2022; Ulukam, 2024). Countries such as China, India, the United States, and Russia are prominent wheat producers, holding strategic positions in international trade and influencing both local economies and the global dynamics of supply and demand. The growing demand for wheat, driven by population growth and changing dietary patterns, makes the sustainability of wheat production a central issue for ensuring economic and food stability on a global scale (Abys *et al*., 2024). The quality of wheat grains is a determining factor in the production of high-value food products and is influenced by a range of genetic, agronomic, and environmental factors. It is characterized by parameters such as protein content, gluten levels, color, grain integrity, and test weight (hectoliter weight), all of which directly affect its suitability for the food industry (Ma *et al.,* 2021). Among these, test weight is the most used parameter in grain commercialization between farmers and the food industry (Kumar *et al*., 2024). Factors such as climate, fertilization, and field management practices significantly impact grain quality, potentially leading to variations that affect both yield and the technological properties of wheat. Microbial activity in the soil and the resulting biological fertility of the soil–plant system play a decisive role in determining wheat test weight. Test weight is directly related to the density and integrity of the grains, reflecting their physical and sanitary characteristics. Soils with high biological fertility, defined by rich microbial biodiversity, elevated organic matter content, and a well-structured soil profile, promote optimal root development in plants, leading to grains with greater mass and density (Hebe *et al*., 2022; Lamlom *et al*., 2023). In this context, the presence of beneficial microorganisms, such as bacteria and fungi, enhances the availability of essential nutrients for wheat, improves soil water retention, and increases the plants' resilience to environmental stressors. Consequently, agricultural practices that foster soil biological health represent effective strategies for enhancing both wheat yield and grain quality. Among the products based on technological innovations with the effect of reestablishing balance in agricultural systems and increase of the crops productivity, the Penergetic technology has attracted the attention of farmers and the scientific community. Research works have already demonstrated the effect of the product on agricultural crops and on the biological activity of soils in different soils around the world (Kadziuliene *et al.,* 2005; Jakiene *et al.,* 2008; Jankauskiene & Surviliene, 2009; Cobucci *et al*., 2015; Souza *et al.,* 2017; Franco Júnior *et al*., 2018; Franco Júnior *et al*., 2019). This study aimed to evaluate the effectiveness of the biostimulant Penergetic in improving wheat productivity and grain quality under different application forms and dosages.

MATERIALS AND METHODS

The experiment was conducted under field conditions at the experimental area of Biomonte Research and Development, located in the municipality of Santa Maria, RS, Brazil, with the following field coordinates: 29º38'48.1"S and 53º57'40.7"W. The experimental area has soil characterized as Dystrophic Red Argisol. The field experiment was carried out from June 25, 2024, to October 23, 2024. The ORS Soberano wheat cultivar, known for its medium cycle and high quality, was used. The crop was established using a no-tillage system, with sowing on June 25, 2024, and emergence on July 2, 2024. The experimental design used was a randomized block design, with 6 treatments and 8 replications. The experimental plots measured 20 meters in width by 50 meters in length, totaling 1000 m². For evaluation purposes, a central useful area of 300 m² was considered. The sowing was performed with a 17 cm row spacing and a seed density of 140 kg per hectare.

Different combinations of the biostimulant Penergetic were applied in liquid form (molasses) and solid form (sikron). The evaluated treatments were: T1: Control treatment (no Penergetic applied); T2: 500g of Penergetic b (sikron) and 500g of Penergetic p (sikron); T3: 1000mL of Penergetic b (molasses) and 500mL of Penergetic p (molasses); T4: 1000mL of Penergetic b (molasses) and 500g of Penergetic p (sikron); T5: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses); T6: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses) + 300g of Penergetic p (sikron). The Penergetic products in solid form were previously mixed with water and added to the spray solution. The Penergetic b products (liquid and solid) were applied 15 days before wheat sowing. The Penergetic p products were applied at the BBCH 13-14 growth stage (Figure 1).

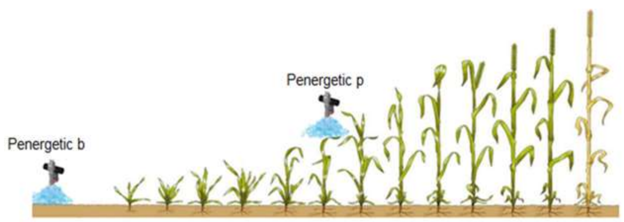

Figure 1. Application scheme of the biostimulant Penergetic in wheat crops

In all treatments, standard fertilization and phytosanitary management practices for wheat in the southern region of Brazil were used. Treatments T2 through T6 were conducted in plots that had been using the Penergetic technology for 2 years. Potassium and phosphate fertilization were omitted, with only nitrogen fertilization (urea) applied at a rate of 200 kg/ha. The applications were carried out on July 13, 2024, and July 16, 2024. Phytosanitary management followed the technical recommendations for wheat cultivation in the southern region of Brazil. Wheat yield was evaluated by grain weight per area, with moisture content adjusted to 12%, and grain quality was determined according to the methodology used by Awulachew (2020). Data were submitted to analysis of variance, with means compared by Tukey's test at a 5% probability of error using statistical software.

RESULTS AND DISCUSSION

The use of the biostimulant Penergetic resulted in an increase in microbial activity in the soil, as shown in the bioanalysis presented in Figure 2. Microbial activity in the soil was significantly higher in treatments T5 and T6, where higher dosages of the biostimulant were used in the combination of liquid and solid forms. According to Akbar *et al*. (2025) and Semenov *et al.* (2025), microbial activity in the soil is a key factor for high-potential regenerative agriculture. The authors suggest that management practices and technologies that increase microbial activity in the soil are essential tools for modern agriculture. The increases in microbial activity in the soil likely resulted in significant differences in plant development in the field, particularly in terms of the health of the wheat's above-ground parts. In treatments where higher dosages of the biostimulant Penergetic were applied (combination of liquid and solid products), the wheat leaves did not show any visible signs of biotic stress during the ear formation stage (Figure 3).

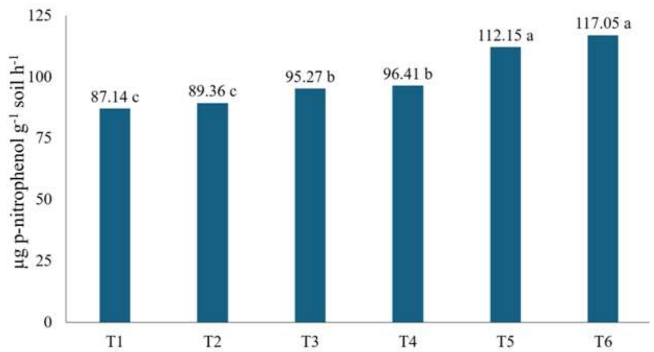

Figure 2. β-glucosidase enzyme activity in the soil under different treatments. Treatments:T1: control;T2: 500g of Penergetic b (sikron) and 500g of Penergetic p (sikron);T3: 1000mL of Penergetic b (molasses) and 500mL of Penergetic p (molasses); T4: 1000mL of Penergetic b (molasses) and 500g of Penergetic p (sikron); T5: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses);T6: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses) + 300g of Penergetic p (sikron).

As a microbial stimulator, Penergetic directly enhances microbial activity in the soil, promoting biological balance (Steffen *et al.,* 2020; Hata *et al.,* 2022). Biological balance in the soil is crucial for plant health as it fosters the interaction between beneficial organisms and the plant root system, resulting in more structured soil with higher biological fertility, better water and nutrient retention capacity, and enhanced plant development and resistance to diseases. It is likely that the improvement in plant health contributed to the increased productivity and quality of wheat grains (Figures 3 and 4). The better the biological fertility of the soil, the better the conditions for maintaining microbial communities that interact with the plant root system, promoting growth and/or plant protection.

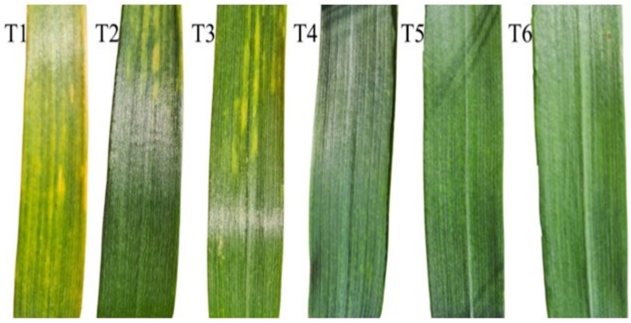

Figure 3. Wheat leaves during the ear formation stage in the different evaluated treatments.Treatments:T1: control;T2: 500g of Penergetic b (sikron) and 500g of Penergetic p (sikron);T3: 1000mL of Penergetic b (molasses) and 500mL of Penergetic p (molasses);T4: 1000mL of Penergetic b (molasses) and 500g of Penergetic p (sikron);T5: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses);T6: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses) + 300g of Penergetic p (sikron).

The establishment of symbioses between plants and microorganisms, as well as between different groups of microorganisms within microbial communities, results in an increase in the diversity of microbial metabolites (acids and organic compounds, hormones, amino acids, peptides, and polysaccharides) that regulate the physiological and biochemical processes of microorganisms and plants in symbiosis (Singh *et al.*, 2024). The direct outcome of these interactions is the improved ability of plants to reach their maximum productive potential and produce higher-quality grains. In this study, all treatments that received the application of the biostimulant Penergetic showed higher wheat productivity compared to the control treatment. The treatments with higher dosages of the biostimulant (through the combination of liquid and solid product applications) resulted in the highest productivity averages. Treatment T6 (1000mL of Penergetic b molasses + 500g of Penergetic b sikron and 500mL of Penergetic p molasses + 300g of Penergetic p sikron) increased wheat grain productivity by 74.9% compared to the control treatment (Figure 4). The average wheat yield in Rio Grande do Sul (Southern Brazil) was 2,839 kg per hectare in the 2024 growing season. Based on this information, it is evident that the average yield achieved with the use of the Penergetic biostimulant holds technical relevance for enhancing grain productivity.The treatments that resulted in higher wheat productivity also exhibited higher grain quality, a parameter evaluated by the size, shape, and uniformity of the grains (Figure 5). The quality of wheat grains is a crucial factor in determining their suitability for different uses, such as flour for baking, food products, or animal feed. Grain quality is influenced by various factors, including climatic conditions, agricultural practices, the genetic characteristics of each cultivar, and, directly, biological quality. The benefits of using the biostimulant Penergetic for wheat productivity and quality have already been studied by researchers from different research institutions (Artyszak & Gozdowski, 2021; Klevinskaitė, 2022; Pekarskas *et al.,* 2011; Pekarskas, 2012; Pekarskas & Sinkevičienė, 2015; Pekarskas *et al.,* 2017; Veverskytė, 2020; Steponavičienė *et al.*, 2021).

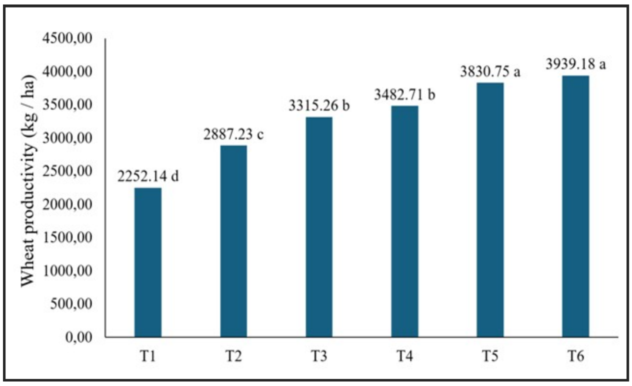

Figure 4. Wheat productivity under the different evaluated treatments.Treatments:T1: control;T2: 500g of Penergetic b (sikron) and 500g of Penergetic p (sikron);T3: 1000mL of Penergetic b (molasses) and 500mL of Penergetic p (molasses);T4: 1000mL of Penergetic b (molasses) and 500g of Penergetic p (sikron);T5: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses);T6: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses) + 300g of Penergetic p (sikron).

The effect of using the biostimulant Penergetic was observed for the hectoliter weight variable (Figure 6). The grains from plants that received the highest doses from the combination of sikron and molasses products showed higher quality of the final product, with hectoliter weight exceeding 80 (Figure 6). This result is very important as it is directly related to the price paid to the producer for the grain to be used in the food industry. Grains with higher hectoliter weight result in flour with better technical properties, such as greater water absorption capacity and higher elasticity, which are essential for bread and other product quality.

Figure 5. Wheat grains obtained from the different evaluated treatments.Treatments:T1: control;T2: 500g of Penergetic b (sikron) and 500g of Penergetic p (sikron);T3: 1000mL of Penergetic b (molasses) and 500mL of Penergetic p (molasses);T4: 1000mL of Penergetic b (molasses) and 500g of Penergetic p (sikron);T5: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses);T6: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses) + 300g of Penergetic p (sikron)

Additionally, higher-quality wheat exhibits greater uniformity and lower risk of contamination by mycotoxins, which adds value to the production, ensuring greater efficiency in the industrial process and better final quality for the consumer. These factors justify the higher payment by the industry, as higher-quality wheat contributes to a superior final product with better yield and less waste during production. The correlation between the biological fertility of the soil and the productive efficiency of the wheat crop was clearly demonstrated in this study. The data obtained reinforce the

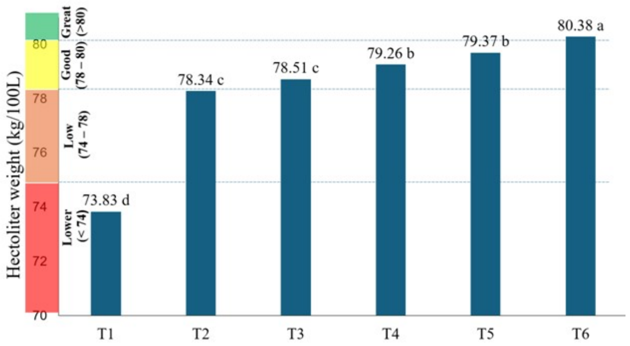

Figure 6. Hectoliter weight obtained from wheat grains under the different evaluated treatments. Treatments:T1: control;T2: 500g of Penergetic b (sikron) and 500g of Penergetic p (sikron);T3: 1000mL of Penergetic b (molasses) and 500mL of Penergetic p (molasses);T4: 1000mL of Penergetic b (molasses) and 500g of Penergetic p (sikron);T5: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses);T6: 1000mL of Penergetic b (molasses) + 500g of Penergetic b (sikron) and 500mL of Penergetic p (molasses) + 300g of Penergetic p (sikron).

importance of agricultural practices and technologies that promote the enhancement of soil biological activity as an effective strategy to increase the quality and productivity of agricultural crops.

CONCLUSION

Increases in productivity and quality indices for the wheat crop were achieved with the use of biostimulants from Penergetic technology. The dosage of the biostimulants and the nature of the commercial products influenced the biological activity of the soil, as well as the productivity and quality of the wheat grains. The combined application of liquid and solid products, along with higher dosages, resulted in greater microbial and productive bio-stimulation. Plants that received the biostimulants exhibited greater health, with direct positive impacts on yield and the qualitative characteristics of the grains. Among the parameters evaluated, hectoliter weight stood out as an indicator of superior quality, reflecting higher commercial value and better industrial performance of the grains. The treatment with the combined application of the biostimulant in both liquid and solid forms at the highest evaluated dosage (1000mL of Penergetic b molasses + 500g of Penergetic b sikron and 500mL of Penergetic p molasses + 300g of Penergetic p sikron) was the most efficient, providing the best results in productivity and quality.

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Competing Interests: The authors declare that there is no conflict of interest of any kind involved incarrying out his scientific research study. Thus, the authors have no competing interests to declare that are relevant to the content of this manuscript.

Data Availability: The datasets generated during the current study are available from the corresponding author on reasonable request.

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