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Effect of microbial consortium application on wheat cultivated in catamarca, Argentina

Abstract

The objective of this study was to determine the effect of applying a microbial consortium on wheat cultivation in the province of Catamarca, Argentina. An inoculant composed of strains of the biocontrol fungus of the genus *Trichoderma spp.*, bacterial strains of *Azospirillum brasilense*, *Bacillus thurigiensis*, *Rhizobium leguminosarum*, and *Bradyrhizobium sp.* was used. A randomized block design was used with two treatments and three replications: one treatment with microbial consortium inoculation and another control treatment. Two applications were made at 5 and 43 days after sowing. The study evaluated wheat yield variables (total grain production, weight of 1000 grains, number of grains per spike, number of spikes per unit area, and harvest index) and growth and development variables of wheat plants (root weight and aerial biomass weight). The results indicate that the application of the microbial consortium significantly increased yields, growth, and development of wheat plants compared to the control treatment. It was determined that applications of selected native microorganisms have a plant growth-promoting effect, increasing the growth and productivity of wheat crops.

Keywords: *Triticum aestivum*, native microorganisms, PGPM, biological control

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Introduction

Triticum aestivum L., commonly known as wheat, belongs to the botanical family Poaceae. The main use of this cereal is human food, but it is also used as forage. It is one of the most important crops grown worldwide, prompting numerous studies aimed at improving its yield.

Wheat yield in a given region results from the interaction between ecological, technological, and genetic factors. Crop nutrition and its management through fertilization are among the main factors limiting wheat production.[1] The primary nutrients limiting wheat productivity in most production areas are nitrogen (N), phosphorus (P), and sulfur (S).[2]

Moreover, the continuous increase in the global population, the progressive reduction of arable land due to urban expansion, soil erosion, soil contamination from toxic product accumulation, and greater restrictions on agricultural trade make it essential to implement strategies and biotechnologies to increase crop productivity. These include using new cultivars of plant species, more productive and better-adapted varieties with greater resistance to phytopathogens and pests, and soil microorganisms that promote plant growth.

Due to the recognized contribution of certain soil microorganisms to plant growth promotion, using them in economically important crops is of interest. Plant growth-promoting microorganisms facilitate plant growth either directly by providing N, P, and essential minerals or by biosynthesizing and regulating hormonal levels, or indirectly by reducing the inhibitory effects of various phytopathogens and acting as biological control agents. They do so through nitrogen fixation, hormone production (such as auxins, cytokinins, gibberellins, ethylene, and other molecules), phosphate solubilization, and indirect growth promotion by protecting plants from soil-borne pathogenic bacteria and fungi.[3-7]

This study aims to contribute to knowledge about wheat cultivation to improve its growth, development, and yield through interactions with microorganisms from the genera *Azospirillum*, *Trichoderma*, *Bacillus*, *Rhizobium*, and *Bradyrhizobium*, forming a microbial consortium. According to López, et al.[8] a "Microbial Consortium" is a natural association of different species that act together as a community in a complex system, where all benefit from each other's activities. This study used microorganisms selected for their plant growth-promoting capacity. Furthermore, it implements environmentally friendly practices while maintaining balance with the ecological conditions of the arid and semi-arid regions of Catamarca, Argentina.

Materials and methods

Direct wheat (*Triticum aestivum*) seeding of the *Don Mario Alerce* variety was conducted on June 1, 2024, in Monte Redondo, Santa Rosa Department, Catamarca Province, Argentina, with a sowing density of 150 kg/ha. A randomized block experimental design was established with two treatments and three replications:

- **Treatment 1:** Control (without inoculation, only water application)
- **Treatment 2:** Inoculation with a microbial consortium (soil application using a manual sprayer)

Three blocks were marked with a 10 m separation. Each block consisted of two experimental plots, each measuring 3 m in length and 3.8m in width. The placement of each treatment in each block was randomized.

The microbial consortium inoculant consisted of a liquid formulation containing three strains of the biocontrol fungus *Trichoderma spp.*, two strains of *Azospirillum brasilense*, one strain of *Bacillus thurigiensis*, one strain of *Rhizobium leguminosarum*, and one strain of *Bradyrhizobium sp.* All strains native to the Central Valley of the Province of Catamarca. The microbial consortium inoculant, named Bio MAsT, was applied twice to the wheat crop using a manual sprayer on the planting line: once at 5 days after sowing with a microbial concentration of 8.3×10^9 PGPR mL^{-1} and again at 43 days after sowing with a concentration of 1.2×10^9 PGPR mL^{-1}, quantified in a Neubauer chamber.[9]

At the end of the crop cycle, samples were taken for evaluation, focusing on the central area of each experimental plot to eliminate edge effects. The sample size of each sample consisted of all wheat plants extracted from a central area of 0.065 m^2 (25 cm length from the two central lines and 26 cm distance between lines).

Parameters for wheat yield evaluation

- Total grain production (kg·ha^{-1} or t·ha^{-1})
- Weight of 1000 grains (g)
- Number of grains per spike
- Number of spikes per unit area
- Harvest index (ratio of grain weight to total aerial biomass weight)

Parameters for wheat plant growth and development evaluation

- Root weight
- Aerial biomass weight

Results were statistically analyzed using analysis of variance (ANOVA), and means were compared using Fisher's Least Significant Difference (LSD) test at a significance level of 0.05 using the Infostat statistical program (Figures 1-3).[10]

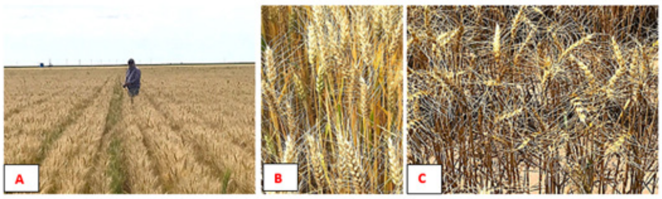

Figure 1 Growth of wheat crop and partial view of the treatments. A: Panoramic view of the wheat crop; B: Inoculated; C: Control.

Figure 2 Samples of wheat plants (*Triticum aestivum*) from each treatment. A: Inoculated; B: Control.

Figure 3 Weight and count of wheat (*Triticum aestivum*) spikes and grains.

Results

The extraction of the plants was carried out 147 days after the wheat crop was sown. The samples were taken to the Agricultural Microbiology Laboratory (Faculty of Agricultural Sciences. National University of Catamarca) for evaluation. In all the yield variables studied, the best results were obtained with the application of the microbial consortium. Statistically significant increases were observed, far exceeding the control treatment, achieving increases of 70% in wheat grain yield, 120% in the number of plants per hectare, and 57% in the number of spikes per hectare (Table 1).

Table 1 Yield parameters of wheat (*Triticum aestivum*) crop.

Parameters	Treatments	
	Control	Inoculated
Total grain production (kg ha^{-1})	9.994,87 **a**	16.902,56 **b**
Number of plants per ha	5.230.769,23 **a**	11.538.461,5 **b**
Number of spikes per ha	10.615.384,62 **a**	16.666.666,67 **b**
Harvest index	0,62 **a**	0,80 **b**

Uncommon letters within the same variable indicate significant differences according to the LSD test (Least Significant Difference) at $P<0.05$.

Statistically significant differences were recorded in the variables number of grains, total grain weight, number and total weight of spikes, with the best results observed in the inoculated treatments. However, in the variables 1000-grain weight and number of grains per spike, no statistically significant differences were obtained (Table 2).

Table 2 Yield parameters of wheat (*Triticum aestivum*) crop per sampling area (0.065 m^2).

Parameters	Treatments	
	Control	Inoculated
Number of grains	1.870,67 **a**	3.154,33 **b**
1000-grain weight (g)	35,23 **a**	34,68 **a**
Grain weight (g)	64,97 **a**	109,87 **b**
Number of grains per spike	26,9 **a**	28,9 **a**
Number of spikes	69 **a**	108,33 **b**
Spike weight (g)	90,37 **a**	145,97 **b**

Uncommon letters within the same variable indicate significant differences according to the LSD test (Least Significant Difference) at $P<0.05$.

Statistically significant differences were observed in the growth and development variables of wheat plants evaluated, achieving the best results with the inoculation of the microbial consortium (Table 3).

Table 3 Growth and development parameters of wheat (*Triticum aestivum*) crop per sampling area (0.065 m^2).

Parameters	Treatments	
	Control	Inoculated
Number of plants	34 **a**	75 **b**
Root weight (g)	297,03 **a**	467,67 **b**
Aerial biomass weight (g)	106,17 **a**	140,13 **b**

Uncommon letters within the same variable indicate significant differences according to the LSD test (Least Significant Difference) at $P<0.05$.

The greater root growth observed in wheat plants to which the microbial consortium was applied allowed the crop to take advantage of a greater amount of water and nutrients available in the soil. This had a very significant effect on the yield variables of the wheat crop, increasing total grain production, total grain weight, total spike

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weight, and the number of spikes per unit area, far surpassing those obtained in the control treatment.

Discussion

Although the first application of the microbial consortium was made to the soil a few days after sowing, it is estimated that seed inoculation would be the most convenient. Due to better contact between the seeds and the inoculant. However, the results obtained showed a remarkable increase in the different evaluated plant production variables (total grain production, number of grains per spike, number of spikes per unit area, harvest index, root weight, and aerial biomass weight) in wheat plants due to inoculations with the selected microorganisms compared to the control plants without inoculation.

The microbial consortium used, composed of native bacterial and fungal strains, generated the best results due to the greater uptake of water and nutrients, mainly nitrogen that can be incorporated into the soil by biological nitrogen fixation, since the bacterium *A. brasilense* has this ability, in addition to synthesizing auxins and other phytohormones.[11] The greater uptake of water and nutrients, especially those that are not very mobile such as phosphorus, facilitates availability and assimilation by plants.[12] Furthermore, these microorganisms locate and colonize sites in the rootlets that could potentially be occupied by phytopathogens.

Torres Duggan[2] considers that biological treatments with *Azospirillum brasilense* bacteria represent a valuable technology for increasing crop productivity, complementing traditional fertilization, and increasing the efficiency of water and nutrient use in the soil.

In recent years, there has been renewed interest in cereal seed treatments (mainly maize and wheat) with bacteria of the genus *Azospirillum*. It is important to emphasize that this type of biological treatment does not replace conventional fertilization but complements it.[2] While *Rhizobium leguminosarum* and *Bradyrhizobium sp.* are well-known bacteria for symbiotic nitrogen fixation in leguminous plants, such as common bean (*Phaseolus vulgaris*) and soybean (*Glycine max*), respectively, there are no previous reports of their use in wheat cultivation. However, these bacteria also have the ability to solubilize phosphorus, and for this function, they were included as part of the inoculants used in this trial. Regarding *Trichoderma spp.* and *Bacillus thuringiensis*, they were incorporated into the inoculant because they are known biological control agents of phytopathogens and pests, although their use in wheat cultivation has not been reported.

Modern nutrient management requires the integration of fertilization with the contribution of atmospheric Biological Nitrogen Fixation and phosphorus solubilization, maximizing crop productivity while minimizing environmental impact.

Moreover, wheat cultivation significantly contributes to soil cover with its crop residues, which have a high C/N ratio and, due to sowing distance, leave residue uniformly distributed on the soil surface, characterized by its durability over time.[13] It is estimated that applying the microbial consortium to the soil will increase biological activity, enhancing organic matter degradation and nutrient cycling, representing a soil fertility management strategy.[14]

Conclusion

Inoculations of the wheat crop (*Triticum aestivum L.*) with selected native microorganisms generated a positive effect on all evaluated variables, improving development and productivity due to better nutrition.

Significant differences were observed in the evaluated variables as a result of the applied treatment, with the yield-related variables being the most consistent.

The application of the microbial consortium significantly increased yields compared to the control treatment.

The microbial inoculants used in this experiment were native species that, due to their origin, demonstrated better adaptation mechanisms to environmental conditions. This is believed to be one of the reasons for the promising results observed in wheat crop growth.

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Conflicts of interest: Authors declare that there is no conflicts of interest.

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