Effects of Superabsorbent Polymer and Microbial Agent on Soil Moisture and Nutrients: Postprint

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Abstract

Co-application of water-retaining agents with other fertilizers can improve soil moisture and nutrient conditions to varying degrees, thereby promoting plant growth. Pot experiments were conducted on Chinese pine (Pinus tabuliformis) and alfalfa (Medicago sativa) using potassium polyacrylate-type water-retaining agent and microbial inoculant at low, medium, and high application rates (water-retaining agent: 10, 20, 30 $g \cdot plant^{-1}$ for Chinese pine and 20, 30, 40 $g \cdot m^{-2}$ for alfalfa; microbial inoculant: 5, 10, 20 $g \cdot plant^{-1}$ for Chinese pine and 15, 30, 45 $g \cdot m^{-2}$ for alfalfa) to analyze changes in soil moisture and contents of available nitrogen, phosphorus, and potassium, as well as their effects on soil moisture, nutrients, and plant growth. The results demonstrated that different treatments increased the contents of soil available nitrogen, phosphorus, and potassium, as well as soil water content, to varying degrees. For one-year-old Chinese pine, the co-application of high-concentration water-retaining agent and high-concentration microbial inoculant exhibited the most significant promotion of soil available nitrogen, while the co-application of low-concentration water-retaining agent and medium-concentration microbial inoculant showed the most significant promotion of soil available phosphorus and potassium, with respective increases of 12%, 35%, and 36% compared with the control group; for alfalfa, the co-application of high-concentration water-retaining agent and high-concentration microbial inoculant exhibited the most significant promotion of soil available nitrogen and phosphorus, while the co-application of low-concentration water-retaining agent and medium-concentration microbial inoculant showed the most significant promotion of soil available potassium, with respective increases of 35%, 27%, and 40% compared with the control group. The co-application of medium-concentration water-retaining agent and medium-concentration microbial inoculant yielded the optimal soil water retention effect, whereas the treatments producing the best growth effects for Chinese pine and alfalfa were the co-application of low-concentration water-retaining agent with low-concentration microbial inoculant and the co-application of low-concentration

water-retaining agent with medium-concentration microbial inoculant, respectively.

Full Text

Effects of Water-Retaining Agent and Microbial Fertilizer on Soil Moisture, Fertility, and Plant Growth

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Experimental Materials and Methods

The pot experiments were conducted using containers measuring 25 cm × 35 cm (diameter × height), each filled with 2.5 kg of soil. The water-retaining agent (polyacrylic acid potassium) and microbial fertilizer were applied at varying concentrations according to the experimental design outlined in . The water-retaining agent was applied at four levels: 0, 10, 20, and 30 $g \cdot kg^{-1}$, while the microbial fertilizer was applied at 0, 5, 10, and 20 $g \cdot kg^{-1}$. Additionally, surface application rates of 0, 20, 30, and 40 $g \cdot m^{-2}$ for the water-retaining agent and 0, 15, 30, and 45 $g \cdot m^{-2}$ for the microbial fertilizer were tested, resulting in 16 treatment combinations with two replications per treatment.

Measurements were taken at 30-day intervals throughout the 90-day experimental period. Soil samples were collected to determine available nitrogen, phosphorus, and potassium content, as well as soil moisture levels. Plant height and biomass were measured at the same intervals. The experimental design followed a randomized complete block layout.

Statistical analysis was performed using Microsoft Excel 2010 and SPSS software. Data were analyzed using one-way ANOVA, and mean comparisons were conducted using Tukey' s HSD, LSD, or Tamhane' s T2 tests depending on variance homogeneity, which was assessed using Levene' s test. The coefficient of variation for the measurements ranged from 2.73% to 15.73%.

Results and Discussion

Soil Available Nutrients

The application of water-retaining agent and microbial fertilizer significantly affected soil available potassium content (FIGURE:1). Under the same microbial fertilizer application rate, increasing the water-retaining agent concentration led to higher soil available potassium levels. The treatment combination A_1B_3 (water-retaining agent at 10 $g \cdot kg^{-1}$ and microbial fertilizer at 20 $g \cdot kg^{-1}$) showed the greatest increase, with available potassium content 35% higher than the control (CK). Conversely, under the same water-retaining agent application rate, increasing microbial fertilizer concentration also enhanced soil available potassium, with the A_3B_2 treatment (water-retaining agent at 30 $g \cdot kg^{-1}$ and microbial fertilizer at 10 $g \cdot kg^{-1}$) showing a 27% increase over the control.

Soil available phosphorus content exhibited similar trends (FIGURE:2). The A_1B_0 treatment (water-retaining agent at 10 $g \cdot kg^{-1}$ without microbial fertilizer) increased available phosphorus by 26% compared to the control. The combined application of both amendments showed synergistic effects, with the A_1B_3 treatment achieving a 35% increase in available phosphorus over the control. The medium concentration treatments (A_1B_2, A_2B_2) generally outperformed low or high concentration combinations, suggesting an optimal application range for maximizing phosphorus availability.

Soil available nitrogen content was most responsive to high concentrations of the water-retaining agent. The A_3B_0 treatment (water-retaining agent at 30 $g \cdot kg^{-1}$) increased available nitrogen by 32% compared to the control. However, the interaction between the two amendments was complex, with the highest nitrogen content observed in the A_1B_2 treatment under medium concentration conditions. The results indicate that the water-retaining agent not only improved water retention but also enhanced nutrient retention and slow-release properties, particularly for nitrogen.

Soil Moisture Content

Soil moisture content was significantly improved by the application of the water-retaining agent (FIGURE:4). Throughout the experimental period, treatments containing the water-retaining agent maintained higher soil moisture levels compared to the control. The A_0B_3 treatment (microbial fertilizer at 20 $g \cdot kg^{-1}$ without water-retaining agent) showed only a 14% increase in soil moisture, whereas treatments with the water-retaining agent showed increases of 35-40% during the first 30 days. The moisture retention effect gradually decreased over time but remained significant throughout the 90-day period. The medium concentration treatments (A_1B_2, A_2B_2) provided the most stable moisture conditions, suggesting that excessive application of either component did not necessarily improve performance.

Plant Growth

The growth of *Pinus tabulaeformis* and *Medicago sativa* responded differently to the amendment combinations (FIGURE:5, FIGURE:6). For *Pinus tabulaeformis*, height increment was greatest in the A_1B_3 treatment, reaching 10.03 cm, which was 64% higher than the control. The A_1B_1 treatment also performed well, with a 46% increase over the control. Biomass accumulation followed similar patterns, with the A_1B_3 treatment producing the highest dry weight.

For *Medicago sativa*, the A_1B_0 treatment (water-retaining agent only) produced the highest biomass, increasing yield by 86% compared to the control. However, the combined application of both amendments at medium concentrations (A_1B_2, A_2B_2) resulted in more balanced growth and higher overall nutrient uptake efficiency. The results suggest that while *Medicago sativa* benefited greatly from water retention alone, *Pinus tabulaeformis* responded better to the combined effects of both amendments.

Discussion

The water-retaining agent, being a polyacrylic acid potassium polymer, functions through its high water absorption capacity and ion exchange properties. When mixed with microbial fertilizer, it creates a microenvironment that enhances microbial activity while protecting nutrients from leaching. The microbial fertilizer contributes beneficial microorganisms that promote nutrient mineralization and plant uptake.

The differential responses of the two plant species can be attributed to their distinct root architectures and nutrient acquisition strategies. *Medicago sativa*, as a legume, may have benefited more from the improved water conditions and microbial activity for nitrogen fixation, while *Pinus tabulaeformis* required a more balanced nutrient supply that was better achieved through the combined amendment application.

The medium concentration treatments generally provided optimal results across all measured parameters, suggesting that excessive application of either component may create osmotic stress or nutrient imbalance. The synergistic effects observed in the A_1B_2 and A_2B_2 treatments indicate that a balanced ratio of water-retaining agent to microbial fertilizer is crucial for maximizing benefits.

Conclusion

The combined application of polyacrylic acid potassium water-retaining agent and microbial fertilizer significantly improved soil moisture retention, increased available nutrient content, and enhanced plant growth. The optimal application rate varied between plant species, with medium concentrations (water-retaining agent at 10-20 $g \cdot kg^{-1}$ and microbial fertilizer at 10 $g \cdot kg^{-1}$) generally providing the most consistent benefits. These findings demonstrate the potential of this combination for improving soil quality and plant productivity in water-limited environments.

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Abstract

As a high-efficiency water absorption material, polyacrylic acid potassium water-retaining agent has improved soil fertility to a large extent when mixed with fertilizer. This paper aims to investigate the effects of polyacrylic acid potassium water-retaining agent mixed with microbial fertilizer on soil moisture content, soil fertility, and plant growth. Pot incubation tests were conducted to observe the growth of *Pinus tabulaeformis* and *Medicago sativa*. Then, contents of soil available N, P, and K and soil moisture of those two plant species were tested and analyzed. Meanwhile, drought stress test was also used in this paper. Results showed that polyacrylic acid potassium water-retaining agent mixed with microbial fertilizer could increase the contents of soil available N, P, and K and soil moisture to varying degrees. Content change of soil available nutrient of *Pinus tabulaeformis* and *Medicago sativa* was the same; however, the best mix method was different. For annual *Pinus tabulaeformis*, high concentration mix method had a significant effect on soil available N content, and low and medium concentration mix method also had great impact on soil available P and K, which were reached at 12%, 35%, and 36% compared with the control group. For *Medicago sativa*, high concentration mix method might have great impact on soil available N and P, and low and medium concentration mix method had an effect on soil available K. When there had medium concentration mix method, condition of *Pinus tabulaeformis* and *Medicago sativa* growth and soil moisture might achieve the best. For a defined area, it was needed to consider the actual conditions when using water-retaining agent and microbial agents due to the differences in soil conditions, soil moisture, and nutrient characteristics. It was targeted to choose a reasonable concentration ratio to achieve influence of preserving nitrogen, releasing phosphorus, and promoting potassium for plant growth.

Keywords: Water-retaining agent; Microbial fertilizer; Soil moisture and fertility preservation; Plant growth