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PHOSPHATE-SOLUBILIZING ACTIVITY OF BACTERIAL STRAINS IMMOBILIZED ON PHOSPHORITE FLOUR AFTER STORAGE

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Phosphate-solubilizing bacteria play an important role in transforming poorly soluble soil phosphorus compounds into forms available for plant uptake. The use of these microorganisms represents a promising approach to developing biological fertilizers that improve phosphorus nutrition in plants.

Immobilization of bacterial cells on mineral and organomineral carriers is a promising strategy for developing effective microbial preparations for agricultural applications. Suitable carriers provide a matrix for cell immobilization, may help maintain microbial viability and functional activity, and facilitate the production and application of biopreparations. Locally available mineral materials, particularly phosphorite flour, are of special interest because they can serve not only as carriers for bacterial cells but also as additional sources of phosphorus-containing compounds.

An important direction in improving microbial fertilizers is the development of dry formulations that are convenient to store, transport, and apply to soil. Immobilization on solid mineral carriers may contribute to maintaining microbial viability during storage and facilitate the release of bacterial cells after application to soil. However, the effectiveness of such preparations depends on the bacterial strain, carrier properties, formulation technology, and storage conditions. Therefore, investigating the phosphate-solubilizing activity of bacteria after storage is important for assessing the potential of phosphorite flour-based dry microbial preparations.

Accordingly, the aim of this study was to evaluate the phosphate-solubilizing activity of bacterial strains immobilized on phosphorite flour and ammonium sulfate-activated phosphorite flour after three months of storage, in order to assess their potential for developing dry microbial formulations.

The study investigated *Bacillus megaterium* strains 5F, 9T, and 22R, *Bacillus subtilis* strain 7R, and *Bacillus proteolyticus* strain 33S immobilized on phosphorite flour (FM) and activated phosphorite flour (FMA). The phosphate-solubilizing activity of *B. megaterium* strains 5F, 9T, and 22R and *B. subtilis* strain 7R was assessed in Pikovskaya medium, whereas that of *B. proteolyticus* strain 33S was evaluated in NBRIP medium. Tricalcium phosphate, $Ca_3(PO_4)_2$, was used as a poorly soluble mineral phosphorus source. Phosphorite flour (FM) and phosphorite flour pretreated with ammonium sulfate (FMA) were used as mineral carriers. The phosphate-solubilizing activity of the immobilized bacterial strains was evaluated by measuring the concentration of soluble phosphorus in the culture medium on days 3, 6, and 10 of cultivation following three months of storage. The results were expressed as mg P_2O_5 per 100 mL.

In Pikovskaya medium, the highest phosphate-solubilizing activity was observed for *B. subtilis* strain 7R immobilized on FM. The soluble phosphorus concentration increased from below

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the detection limit on day 3 to 2.65 mg P_2O_5/100 mL on day 6 and 40.85 mg P_2O_5/100 mL on day 10. When FMA was used as the carrier, the corresponding values were below the detection limit, 1.70, and 5.59 mg P_2O_5/100 mL. On day 10, the soluble phosphorus concentration in the FM treatment was approximately 7.3 times higher than that in the FMA treatment.

For *B. megaterium* strain 5F immobilized on FMA, the soluble phosphorus concentration was 1.06 mg P_2O_5/100 mL on day 3, increased to 1.24 mg P_2O_5/100 mL on day 6, and subsequently decreased to 0.86 mg P_2O_5/100 mL on day 10. In *B. megaterium* strain 9T, the concentration increased progressively from 0.72 to 0.78 and 1.28 mg P_2O_5/100 mL on days 3, 6, and 10, respectively. For *B. megaterium* strain 22R, the soluble phosphorus concentration was below the detection limit on day 3, reached 0.24 mg P_2O_5/100 mL on day 6, and increased to 0.61 mg P_2O_5/100 mL on day 10.

In NBRIP medium, *B. proteolyticus* strain 33S immobilized on FM showed soluble phosphorus concentrations below the detection limit on days 3 and 6, followed by an increase to 29.64 mg P_2O_5/100 mL on day 10. When FMA was used as the carrier, the concentrations were also below the detection limit on days 3 and 6, whereas the value on day 10 reached 1.86 mg P_2O_5/100 mL. Thus, the final soluble phosphorus concentration in the FM treatment was approximately 15.9 times higher than that in the FMA treatment.

Following three months of storage, the immobilized bacterial preparations retained the ability to promote the accumulation of soluble phosphorus during subsequent cultivation. The highest final values were recorded for *B. subtilis* strain 7R immobilized on phosphorite flour in Pikovskaya medium (40.85 mg P_2O_5/100 mL) and *B. proteolyticus* strain 33S immobilized on phosphorite flour in NBRIP medium (29.64 mg P_2O_5/100 mL). These findings indicate the potential of phosphorite flour as a mineral carrier for phosphate-solubilizing bacteria in the development of microbial fertilizers.

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