

INFLUENCE OF MICROBIOLOGICAL PREPARATIONS ON MICROFLORA AND AGROCHEMICAL PROPERTIES OF SALINE SOILS IN COTTON GROWING

Zakiryayeva S.I., Karimov H.X., Shakirov Z.S. and Khamidova H.M.
The Institute of Microbiology, Academy of Sciences of the Republic of Uzbekistan

<https://doi.org/10.35410/IJAEB.2025.5990>

ABSTRACT

In this study, the effect of microbiological preparations on the microbiological and agrochemical properties of highly saline soil (0–30 cm) during cotton cultivation was investigated. The use of preparations contributed to an increase in the number of all studied physiological groups of microorganisms. The number of ammonifiers, fungus and cellulose-decomposing microorganisms increased by 1 order of magnitude, and humus-decomposing microorganisms by 2 orders of magnitude. The appearance of phosphorus-mobilizing bacteria, previously absent in the original soil, was noted. Positive changes in the agrochemical composition of the soil were also revealed: the content of mobile phosphorus increased by 3.8 mg/kg, and the amount of mobile potassium decreased by 102.6 mg/kg. A decrease in soil pH from 7.95 to 7.45 and a decrease in total salinity from 1.72 to 0.09% were noted, which indicates improved conditions for plant growth and the activity of soil microorganisms. The obtained results confirm the effectiveness of using microbiological preparations in increasing the biological activity and fertility of saline soils.

Keywords: Microbiological Preparations, Saline Soil, Microbial Community, Agrochemical Properties, Humus, Cotton, Phosphorus Mobilization.

1. INTRODUCTION

Soil microorganisms play an important role in maintaining soil fertility by participating in the regulation of nutrient and organic carbon cycling and by increasing their availability to plants [1-4]. They are key participants in biological processes that ensure the mobilization and transformation of nitrogen and phosphorus in the soil environment [5]. However, soil salinization has a significant impact on the composition and activity of the microbial community [6], exceeding in scale the impact of such extreme factors as temperature and pH [7]. Soil salinization disrupts the availability of nitrogen (N) and carbon (C) compounds [8], changes their migration and transformation, which ultimately affects the biogeochemical cycle and productivity of agroecosystems [9, 10].

Microbial biomass plays a crucial role in maintaining phosphorus availability. Soil microorganisms significantly improve the absorption of nutrients by plants by catalyzing the conversion of phosphorus in organic and inorganic pools [11]. Microorganisms carry out the main soil-biological process - the decomposition of plant residues with the subsequent formation of new organic matter, in particular, humus. In addition, using root secretions of plants in the process of their life activity, microorganisms help to cleanse the soil environment and create favorable conditions for the normal growth and development of agricultural crops.

Biological processes in saline soils, as a rule, proceed with less intensity compared to non-saline soils. This is explained by the impact of stressful climatic factors, including high

summer temperatures, low air humidity, active evaporation of moisture from the soil surface and low organic matter content. Together with salinity, such conditions significantly limit the development of microbial activity in the soil [12]. Nevertheless, even under conditions of high salt load and anthropogenic impact, specialized microbial communities adapted to extreme environmental factors are formed in the soil environment. In the conditions of sustainable agriculture, special attention is paid to biological methods of increasing fertility, especially on degraded soils subject to salinization. Saline soils are characterized by a deteriorated structure, low biological activity and reduced availability of nutrients for plants. This problem is especially acute in irrigated agricultural regions, where cotton is widely grown - a crop sensitive to salinity conditions.

One of the promising areas is the use of microbiological preparations containing physiologically active strains of microorganisms. Such preparations are capable of not only activating microbial processes in the rhizosphere, but also improving the agrochemical properties of the soil, promoting better absorption of nutrients and reducing stress in plants.

In this regard, the purpose of this study was to study the effect of microbiological preparations on the composition of the microbial community and agrochemical indicators of saline soils when growing cotton.

2. MATERIALS AND METHODS

The object of the study is highly saline irrigated soils of the south of Uzbekistan (Kashkadarya region, Nishan district), used for cotton sowing.

The microbial community of the saline soil was studied according to the generally accepted method of Zvyagintsev D.G. [13]. Soil samples for microbiological analysis were collected in the spring (before sowing cotton) and in the fall (at the cotton ripening phase) of 2024. Samples were collected according to the envelope principle, maintaining sterility from a depth of 0-30 cm according to the method. Microorganisms of the studied groups were seeded using the deep method from various dilutions of the soil suspension on the following nutrient media: Czapek medium for growing micromycetes, meat-peptone agar (MPA) for ammonifying bacteria, Pikovskaya medium for phosphorus-mobilizing microorganisms, Ashby medium for oligonitrophilic microorganisms, starch-ammonia agar (SAA) for actinomycetes and microorganisms using mineral forms of nitrogen, Getchenson medium for cellulose-decomposing microorganisms, soil agar medium for humus-decomposing microorganisms. The crops were placed in a thermostat at a temperature of 28 °C. Micromycetes were counted on the 7th day after sowing, ammonifiers - on the 3rd day, oligonitrophils and actinomycetes - on the 10th day, humus and cellulose-decomposing microorganisms - on the 12th day. The number of microorganisms was calculated in colony-forming units (CFU) per gram of absolutely dry soil.

Agrochemical analyses of soils were carried out using generally accepted methods in agrochemistry. The pH value - hydrogen index is measured by a standard mercury chloride electrode with automatic temperature compensation. In soil samples, the pH value is measured in an aqueous suspension of 1:5. Humus content was determined by the Tyurin method, gross forms of nitrogen and phosphorus were determined by the Ginzburg et al. method, the content of mobile nitrogen N-NH₄ and mobile phosphorus - P₂O₅ - by the colorimetric method, exchangeable potassium K₂O - by the flame photometry method [14]. The degree of soil salinization was determined by analyzing the water extract. The method is based on the content of water-extractable salts in the soil (TSS).

When cultivating cotton on highly saline soil, the microbiological preparations "Mikroustirgich" and "Azos.uz" were used. In the cotton growth phase, the first treatment was carried out by a single irrigation with the microbiological preparation "Azos.uz" together with irrigation water. In the cotton budding phase, repeated treatment was carried out by a single suspension with the microbiological preparation "Mikroustirgich".

Statistical processing of experimental data was carried out using standard methods for calculating errors, averages, confidence intervals, standard deviations. All calculations and mathematical analyses were performed using Microsoft Excel 2017.

3. RESULTS AND DISCUSSION

Before sowing cotton seeds (March 2024), soil samples of the original saline soil were collected. Agrochemical and microbiological analyses of the original soil were carried out.

The results of the agrochemical analysis of the original soil indicate the presence of signs of degradation caused by secondary salinization and nutrient imbalance. The total salt content was 1.72%, which corresponds to saline soils. The electrical conductivity of the soil solution reached 3.79 dS/m, which significantly exceeds the permissible level for most crops and indicates a high concentration of soluble salts. The reaction of the environment is close to alkaline (pH = 7.95), which limits the availability of elements such as phosphorus, iron, zinc and manganese due to the formation of poorly soluble compounds. The humus content is only 0.611%, indicating a low level of organic matter. This leads to disruption of the soil structure, a decrease in microbiological activity and a weakening of the buffering capacity of the soil. Of particular concern is the high potassium content - $K_2O=250$ mg/kg, which is well above the optimal values. Excess potassium can cause cation imbalance, especially with respect to calcium and magnesium, which worsens the structural condition of the soil and can aggravate salt stress [15]. The level of total nitrogen in the soil is 0.04%, and mobile phosphorus (P_2O_5) is only 10.5 mg/kg, which is below the agronomically necessary values. This limits plant growth, especially in alkaline and saline soils. The soil density is 1.91 g/cm³, indicating compaction, which reduces water and air exchange, as well as root penetration. Such compaction is usually associated with low organic matter content and physical degradation of the soil structure. Thus, a complex combination of high salinity, alkaline reaction of the environment, low humus and nitrogen content, as well as an imbalance in potassium and phosphorus indicates an unfavorable agrochemical state of the soil (Fig. 1).

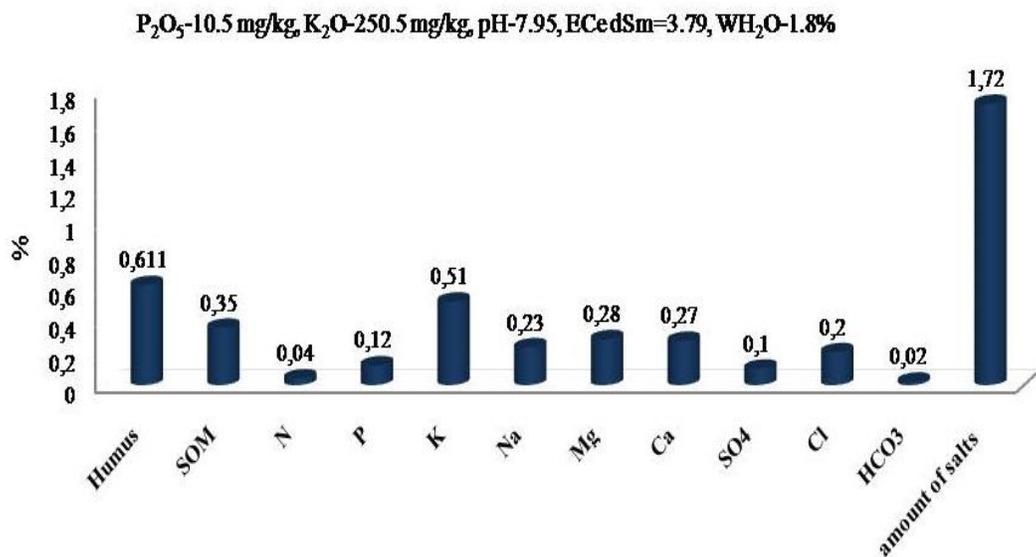


Fig. 1. Agrochemical composition of the original soil of the Kashkadarya region, Nishan district (0-30 cm)

Based on the results of microbiological analyses, it was established that in the original soil there is a sharp decrease in the number of the main physiological groups of microorganisms - 2-3 orders of magnitude below the norm (Fig. 2). Such a decrease in biological activity indicates a significant disruption of the microbial balance and degradation of the soil microbiocenosis.

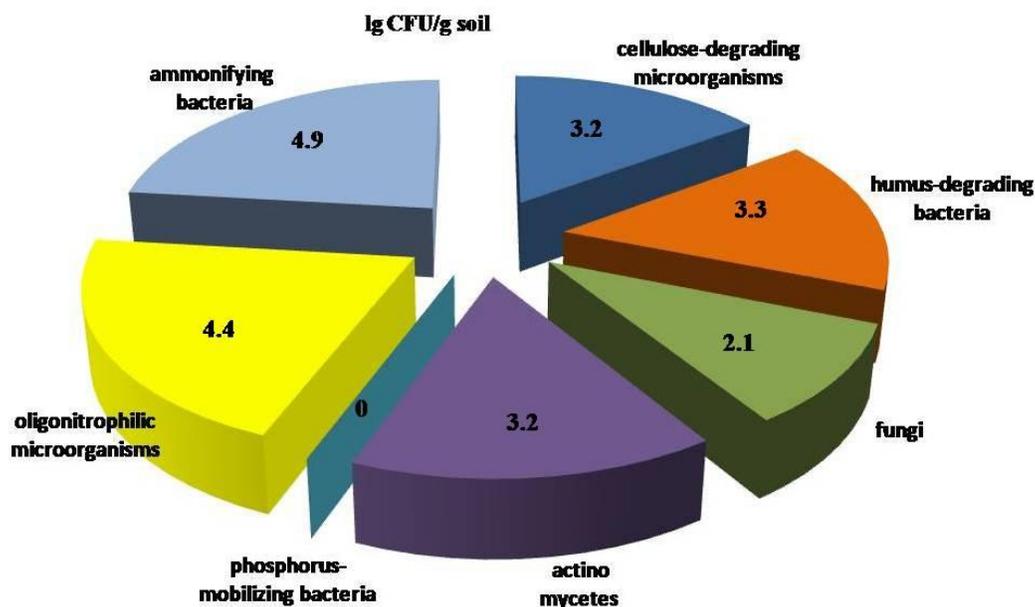


Fig. 2. Microbial community of the original saline soil of the Kashkadarya region, Nishan district (0-30 cm)

One of the key factors that caused such a sharp suppression of soil microflora is the high level of salinity. As shown in the studies of Rietz and Haynes [16], excess salts exert a

pronounced osmotic stress on the cells of microorganisms, reducing their viability and enzymatic activity. The reaction of the soil solution, which in this soil is pH 7.95, also plays an important role. The alkaline environment limits the activity of a number of metabolic pathways in sensitive groups of microorganisms - especially nitrogen fixers, cellulose-decomposing bacteria and mycorrhizal fungi [17]. Low humus content further aggravates the degradation of microbiota. Soil organic matter is the main source of carbon and energy for heterotrophic microorganisms. Its deficiency leads to the suppression of saprophytic bacteria, actinomycetes and representatives of the genera *Bacillus* and *Pseudomonas*, which disrupts important trophic chains in the microbiocenosis. Violation of the physical structure of the soil also affects the number of microbial communities. The soil density of 1.91 g/cm³ indicates its compacted state, which limits gas exchange and water permeability. This leads to anaerobic conditions that suppress aerobic microflora and provoke the development of pathogenic microorganisms [18]. An additional stress factor is the imbalance of ions in the soil solution, especially with an excess of potassium (up to 250 mg/kg in the form of K₂O). High concentrations of individual cations can cause ionic stress in microbial cells and disrupt osmotic regulation, which also reduces population density [19].

We studied the effect of microbiological preparations on the development of soil microbial community in highly saline soil in the 0-30 cm layer. The use of the microbiological preparation resulted in an increase in the number of all studied physiological groups of microorganisms in the cotton ripening phase. The number of ammonifiers, micromycetes and cellulose-decomposing microorganisms increased by 1 order of magnitude (from 4.9-2.1-3.2 to 5.8-3.2-4.4 lg CFU/g soil), and humus-decomposing microorganisms by 2 orders of magnitude (from 3.3 to 5.1 lg CFU/g soil), compared to the original soil. The number of oligonitrophils and actinomycetes increased insignificantly (from 4.4-3.2 to 4.7-3.5 lg CFU/g soil), respectively. The use of a microbiological preparation allowed the emergence of phosphorus-mobilizing bacteria, which amounted to 4.8 lg CFU/g soil, while they were not detected in the original soil (Fig. 3).

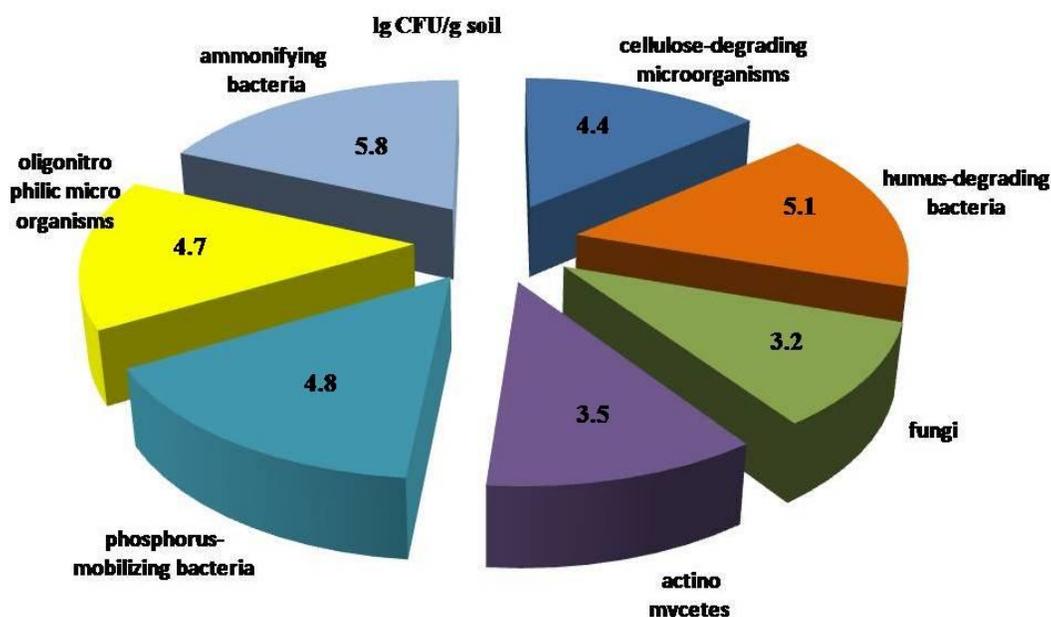


Fig. 3. The influence of microbiological preparations on the microbial community of saline soils under cotton in the Kashkadarya region, Nishan district

Next, we studied the effect of microbiological preparations on the agrochemical composition of highly saline soils in the 0-30 cm layer. The use of microbiological preparations has a significant effect on the content of mobile forms of nitrogen and phosphorus assimilated by plants. The content of mobile phosphorus in the cotton ripening phase increases by 3.8 mg/kg. The humus content increased by 0.003%, total phosphorus and potassium by 0.04%. The amount of mobile potassium decreased by 102.6 mg/kg, which indicates that potassium was well absorbed by cotton plants. The electrical conductivity of the soil solution decreased to 0.23 dS/m, respectively. Soil pH affects the composition and activity of microbial communities, which in turn affects the availability of nutrients [20]. The use of microbiological preparations led to a decrease in the soil pH value from 7.95 to 7.45 units, and the sum of salts from 1.72 to 0.09%. (Fig. 4).

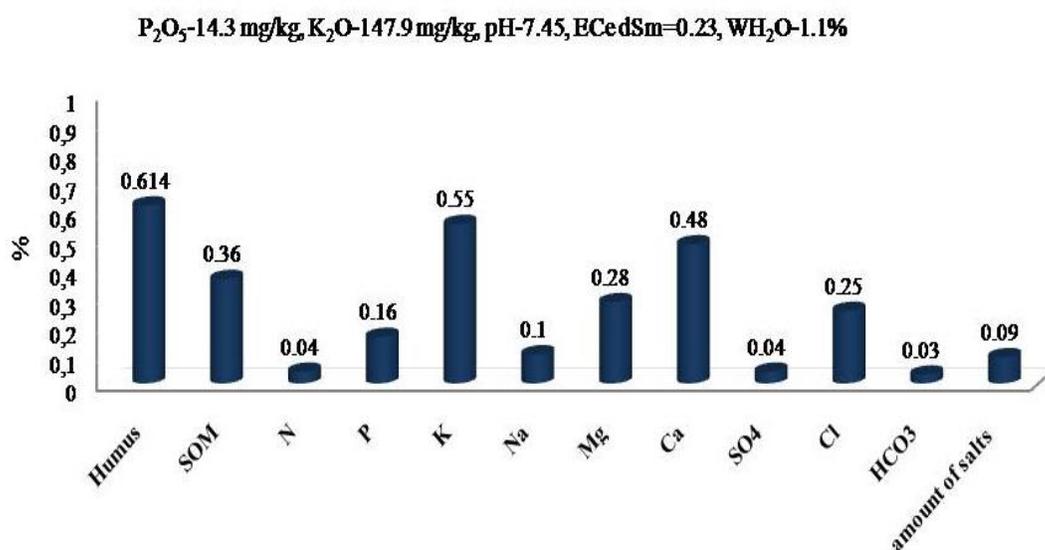


Fig. 4. The influence of microbiological preparations on the agrochemical composition of saline soils under cotton in the Kashkadarya region, Nishan district

4. CONCLUSION

The use of microbiological preparations in highly saline soils contributes to a significant increase in the number of the main physiological groups of microorganisms, including ammonifiers, micromycetes, cellulose and humus-decomposing microorganisms. The preparations contribute to the appearance of phosphorus-mobilizing bacteria that were not previously found in the original soil. Improvement of the agrochemical properties of the soil is manifested in an increase in the content of mobile phosphorus, total phosphorus and potassium, as well as humus. A decrease in pH and total salinity of the soil indicates the normalization of the soil environment and the creation of favorable conditions for microbiological activity and the absorption of nutrients by plants. Microbiological preparations are an effective means of restoring the fertility of saline soils and improving their agroecological state.

REFERENCES

1. Yin C., Liu H., Zhao J., Feng L., Guo S., Li Y., Li X. (2025). The Effects of Biomass Materials and Nitrogen Application on the Composition of the Microbial Community in Moderately Saline Soils. *Agronomy*, 15, 114. <https://doi.org/10.3390/agronomy15010114>
2. Kuypers M.M.M., Marchant H.K., Kartal B. (2018). The microbial nitrogen-cycling network. *Nat Rev Microbiol*. 16(5). P. 263-276. doi: 10.1038/nrmicro.2018.9
3. Wang B., An S., Liang C., Liu Y., Kuzyakov Y. (2021). Microbial necromass as the source of soil organic carbon in global ecosystems. *Soil Biol. Biochem.* 162, 108422. <https://doi.org/10.1016/j.soilbio.2021.108422>
4. Yao Q., Li Z., Song Y. et al. (2018). Community proteogenomics reveals the systemic impact of phosphorus availability on microbial functions in tropical soil. *Nat Ecol Evol*. 2, P. 499–509 <https://doi.org/10.1038/s41559-017-0463-5>
5. Xu Z., Shao T., Lv Z., Yue Y., Liu A., Long X., Zhou Z., Gao X., Rengel Z. (2020). The mechanisms of improving coastal saline soils by planting rice. *Sci Total Environ*. 703:135529. doi: 10.1016/j.scitotenv.2019.135529
6. Shrivastava P., Kumar R. (2015). Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. *Saudi J Biol Sci*. 22(2):123-31. doi: 10.1016/j.sjbs.2014.12.001
7. Ma B., Gong J. (2013). A meta-analysis of the publicly available bacterial and archaeal sequence diversity in saline soils. *World J. Microbiol Biotechnol* 29, P. 2325–2334. <https://doi.org/10.1007/s11274-013-1399-9>
8. Poffenbarger H.J., Needelman B.A., Magonigal J.P. (2011). Salinity Influence on Methane Emissions from Tidal Marshes. *Wetlands* 31, 831–842. <https://doi.org/10.1007/s13157-011-0197-0>
9. Stevenson F.J. (2015). Nitrogen-organic forms. In *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties*; American Society of Agronomy: Madison, WI, USA. P. 625–641. <https://doi.org/10.2134/agronmonogr9.2.2ed.c32>
10. Setia R, Smith P, Marschner P, Gottschalk P, Baldock J, Verma V, Setia D, Smith J (2012). Simulation of salinity effects on past, present, and future soil organic carbon stocks. *Environ Sci Technol* 46(3):1624–1631. <https://doi.org/10.1021/es2027345>
11. Katsalirou E, Deng S, Gerakis A, Nofziger DL (2016) Long-term management effects on soil P, microbial biomass P, and phosphatase activities in prairie soils. *Eur J Soil Biol* 76:61–69. <https://doi.org/10.1016/j.ejsobi.2016.07.001>
12. Rath Kristin M., Rousk Johannes (2015). Salt effects on the soil microbial decomposer community and their role in organic carbon cycling: A review. *Soil Biology and Biochemistry* 81. P. 108-123.
13. Zvyagintsev D.G. (1991) *Methods of soil microbiology and biochemistry*. Moscow.- 350 p.
14. *Methods of agrochemical, agrophysical and microbiological studies in irrigated cotton areas* (edited by MA Belousov). 1963 (Soyuz NIKHI),- 438 p.
15. Anna Tedeschi, Giovanna Angelino, Celestino Ruggiero (2006). Physical and chemical properties of long-term salinized soils. *Italian Journal of Agronomy*. Vol.1, Issue 2, P. 263-269. <https://doi.org/10.4081/ija.2006.263>

16. Rietz D.N, Haynes R.J (2003). *Effects of irrigation-induced salinity and sodicity on soil microbial activity. Soil Biology and Biochemistry. Vol. 35, Issue 6, P. 845-854.* [https://doi.org/10.1016/S0038-0717\(03\)00125-1](https://doi.org/10.1016/S0038-0717(03)00125-1)

17. Sylvia D.M., Hartel P.G. Fuhrmann J.J., Zuberer D.A. (2005). *Principles and Applications of Soil Microbiology (2nd ed.)*. Edited by David M. Sylvia, Pearson Prentice Hall, Upper Saddle River, New Jersey.

18. Pagliai M., Vignozzi N., Pellegrini S. (2004). *Soil structure and the effect of management practices. Soil Till. Res. 79. P. 131-143* <https://doi.org/10.1016/j.still.2004.07.002>

19. Yan S., Zhang T., Zhang B., Zhang T., Cheng Y., Wang C., Luo M., Feng H., Siddique K. H. M. (2023). The higher relative concentration of K⁺ to Na⁺ in saline water improves soil hydraulic conductivity, salt-leaching efficiency and structural stability, SOIL, 9, 339–349, <https://doi.org/10.5194/soil-9-339-2023>

20. Aciego Pietri J.C., Brookes P.C. (2008). Relationships between soil pH and microbial properties in a UK arable soil. *Soil Biol. Biochem.* 40(7). P.1856-1861. <https://doi.org/10.1016/j.soilbio.2008.03.020>