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Article

Integrated Effects of Soil Salinity, Nutrient Limitations and Biofertilizer Application on Rosa Canina Productivity in Arid Soils of Uzbekistan

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Abstract: Rosa canina L. is widely cultivated as a medicinal plant; however, its productivity under arid conditions is often limited by soil salinity and nutrient imbalance. The present study was carried out in the Bukhara region of Uzbekistan to evaluate soil salinity, agrochemical properties, and their influence on the productivity of Rosa canina, as well as to assess the potential role of a microbiological biofertilizer (TERIA-S). Soil samples (0–30 cm) were collected from representative plantation sites and analyzed for physicochemical and elemental composition using standard laboratory methods and EDXRF analysis. The results showed that soils were slightly alkaline (pH 7.6) and affected by moderate to strong salinity (ECe 5.20–8.12 dS/m). The dominant salts were chlorides and sulfates, with NaCl contributing significantly to salinity stress. Although soils contained relatively high total amounts of macroelements (Ca, K, Mg), the availability of key nutrients, particularly phosphorus and potassium, was limited due to calcareous conditions. Agrochemical analysis revealed moderate humus content (1.07%) but low total nitrogen and potassium reserves, along with critically low available phosphorus. These constraints were reflected in the productivity of Rosa canina, which ranged from 5.0 to 6.0 t/ha under field conditions. The application of the microbiological biofertilizer TERIA-S resulted in a yield increase of 8–12% compared to untreated plants and improved overall plant vigor. The findings indicate that soil salinity and nutrient availability are the main limiting factors for Rosa canina cultivation in the studied area. The use of microbiological biofertilizers can partially mitigate these limitations by enhancing nutrient mobilization and improving soil biological activity. This study provides practical insights for improving the productivity of medicinal plants under arid soil conditions.

Keywords: Rosa canina L.; soil salinity; nutrient availability; biofertilizer; arid soils; productivity; Uzbekistan.

Introduction

Soil conditions and environmental constraints are among the most important factors influencing the growth and productivity of medicinal plants in arid and semi-arid regions [1]. In such environments, limited precipitation, high evaporation rates, and extreme temperature fluctuations create persistent stress conditions for plant development. These factors are particularly critical for

perennial medicinal shrubs such as Rosa canina L., which is widely valued for its fruits rich in vitamins, antioxidants, and bioactive compounds [2].

In Uzbekistan, especially in the Bukhara region, agroecosystems are characterized by low annual rainfall, high summer temperatures, and progressive soil degradation processes. These include salinization, alkalization, and nutrient depletion, which collectively reduce soil fertility and agricultural productivity [3]. Under such conditions, even relatively tolerant perennial species experience reduced growth and yield instability.

A major limitation in these soils is the low availability of plant nutrients despite the presence of relatively high total mineral content. In calcareous soils, phosphorus and potassium are often immobilized through reactions with calcium and silicate compounds, forming insoluble complexes such as $Ca_3(PO_4)_2$ and potassium aluminosilicates [4]. This reduces nutrient uptake efficiency and limits plant physiological performance.

Soil salinity further intensifies these constraints by disrupting osmotic balance, reducing water uptake, and inhibiting nutrient transport processes within plants. High pH conditions additionally reduce the solubility of micronutrients such as Fe, Zn, and Mn, which are essential for enzymatic activity and metabolic regulation [5]. As a result, plant growth, biomass accumulation, and reproductive development are significantly affected.

In recent years, increasing attention has been given to sustainable soil management strategies aimed at improving nutrient availability and reducing salinity stress. Among these, microbiological biofertilizers have gained importance due to their ability to enhance soil biological activity and nutrient cycling [6]. These biofertilizers contain beneficial microorganisms capable of solubilizing phosphorus and potassium through organic acid production and enzymatic processes.

The biofertilizer TERIA-S used in this study consists of salt-tolerant microbial consortia with multifunctional properties, including nutrient solubilization and participation in nitrogen cycling. Such microorganisms improve nutrient availability in forms accessible to plants and enhance soil biological balance under stress conditions.

Despite growing research on biofertilizers, limited information is available regarding their combined effects with soil salinity and nutrient limitations in Rosa canina cultivation under arid conditions of Uzbekistan. In particular, the interaction between salinity stress, nutrient availability, and microbial amendments remains insufficiently studied.

Therefore, the objectives of this study were: (i) to assess the physicochemical and elemental composition of soils in Rosa canina plantations in the Bukhara region, (ii) to evaluate soil salinity and nutrient status under field conditions, and (iii) to analyze the potential role of microbiological biofertilizer TERIA-S in improving soil fertility and plant productivity under arid environments.

Materials and Methods

The study was conducted in the Bukhara region of Uzbekistan, an arid agroecological zone characterized by a sharply continental climate. The region experiences hot, dry summers and cold winters with strong seasonal temperature fluctuations. Average annual precipitation ranges from 100 to 200 mm, most of which occurs during winter and early spring. The mean annual temperature is 14–16 °C, while summer temperatures frequently reach 38–42 °C, and winter temperatures may drop to –5 to –10 °C. High evaporation rates combined with low rainfall contribute to soil salinization and reduced moisture availability, which strongly affect agricultural productivity.

The study was carried out on Rosa canina L. plantations established under natural field conditions in the Bukhara region. Rosa canina is a perennial shrub (1–3 m height) cultivated for its medicinally valuable fruits (hips). Experimental observations were conducted under existing farm management practices without introducing artificial agronomic modifications, in order to reflect real production conditions.[7]

Soil samples were collected from the rhizosphere zone at a depth of 0–30 cm, which represents the main active layer for nutrient uptake. Sampling was carried out from three positions within each plantation site (beginning, middle, and end) to account for spatial variability. Composite samples were prepared by mixing equal portions of subsamples. All samples were air-dried at room temperature, homogenized, and passed through a 2 mm sieve prior to analysis.

Soil pH and electrical conductivity (EC) were determined using standard soil analysis procedures. Salinity levels were interpreted according to established classification systems for arid soils.[8]

Elemental composition, including macro-, micro-, and trace elements, was analyzed using energy-dispersive X-ray fluorescence (EDXRF) spectrometry (Rigaku NEX CG, Japan). The instrument was calibrated according to manufacturer guidelines, and measurements were performed under standardized laboratory conditions. Concentrations of elements such as Si, Ca, K, Mg, Na, Fe, Al, Zn, Cu, Ni, Cr, Pb, As, Sr, and U were determined and expressed as percentage or trace concentration values.

Soil samples were additionally analyzed for humus content, total nitrogen, available nitrogen (NO_3^-), total phosphorus, available phosphorus (P_2O_5), total potassium, and mobile potassium (K_2O) using standard agrochemical laboratory methods. Nutrient supply levels were classified according to established soil fertility rating scales for arid and semi-arid regions.

The microbiological biofertilizer TERIA-S was evaluated as a soil amendment. TERIA-S contains a consortium of salt-tolerant microorganisms with functional capabilities including phosphorus, potassium, and silicon solubilization, as well as involvement in nitrogen cycling processes.[9]

Field experiments were conducted using a simple comparative design consisting of two treatments: (1) control (no biofertilizer application) and (2) TERIA-S application. The biofertilizer was applied at the recommended agronomic rate. Treatments were maintained under identical field conditions throughout the growing season.

Plant productivity was evaluated based on field observations and yield records. Parameters included plant height, number of fruits per plant, and total yield per hectare (t/ha). Yield data were collected during the fruiting period under natural field conditions. The relationship between soil properties and plant productivity was assessed based on observed variations across sampling sites.[10]

Results

3.1. Soil Salinity Status and Chemical Composition

Soil salinity analysis showed that Rosa canina plantations in the Bukhara region are characterized by moderate to strong salinity levels. Electrical conductivity (ECe) ranged from 5.20 to 8.12 dS/m.

The dominant soluble salts were NaCl, $CaSO_4$, $MgSO_4$, and Na_2SO_4, with minor presence of $Ca(HCO_3)_2$. Total salt content was higher in cut plant soil (0.646%) than in mature plant soil (0.383%). Soil pH remained constant at 7.6 in both sites (Table 1).[11]

Table 1. Salt composition and salinity characteristics of soils in Rosa canina L. plantations

No	Indicator	1 - Cut plant soil	2 - Mature plant soil
1	ECe (dS/m)	8.12	5.20
2	$Ca(HCO_3)_2$	0.016	0.020
3	$CaSO_4$	0.170	0.153
4	$MgSO_4$	0.149	0.077
5	Na_2SO_4	0.001	0.028
6	NaCl	0.312	0.104
7	$MgCl_2$	–	–
8	Total salts	0.646	0.383
9	Salinity degree	Strongly saline, chloride type	Moderately saline, chloride type

10	pH	7.6 (slightly alkaline)	7.6 (slightly alkaline)

3.2. Macro- and Microelement Composition

EDXRF analysis showed that silicon was the dominant element (22.6–23.1%). High levels of Ca (9.02–9.10%), Al (6.32–6.53%), Fe (3.29–3.32%), K (1.97–2.02%), Mg (2.00–2.01%), and Na (1.25–1.35%) were recorded.

Trace elements (S, Cl, Mn, Ba, Br, Ag) were present at low concentrations. Chlorine content was higher in the first sample (0.297%) than in the second (0.124%) (Table 2).

Heavy metals (Zn, Pb, Cu, Ni, Cr, Co, As, Sr, U) were detected at low natural background levels.[12]

Table 2. Macro-, microelement and heavy metal composition of soils (EDXRF analysis)

Element	1st soil sample (%)	2nd soil sample (%)
K	1.97	2.02
Ca	9.02	9.10
Mg	2.00	2.01
Na	1.35	1.25
Ba	0.0744	0.0793
Mn	0.0733	0.0492
Fe	3.29	3.32
Si	22.6	23.1
S	0.199	0.202
Al	6.32	6.53
Br	0.0007	0.0008
Ag	0.0009	0.0014
Cl	0.297	0.124
Zn	0.0087	0.0087
Sr	0.0314	0.0327
Pb	0.0029	0.0028
Cu	0.0049	0.0048
Co	0.0104	0.0147
Ni	0.0051	0.0029
Cr	0.0066	0.0051
As	0.0016	0.0016
U	0.0006	0.0007

3.3. Agrochemical Properties of Soils

Humus content was stable (1.071–1.072%). Total nitrogen content was low (0.072–0.074%), while nitrate nitrogen was high (68.0–71.5 mg/kg).

Total phosphorus ranged from 0.160% to 0.165%, while available phosphorus was low (19.0 mg/kg). Total potassium content was very low (0.54–0.57%), while mobile potassium ranged from 178.2 to 240.8 mg/kg (Table 3).[13]

Table 3. Agrochemical properties and nutrient supply status of soils under different Rosa canina management stages

No.	Agrochemical indicators	Sample 1 (Pruned rosehip)	Supply level	Sample 2 (Mature rosehip)	Supply level
1	Humus, %	1.071	Moderate	1.072	Moderate
2	Carbon in humus, %	0.623	–	0.623	–
3	Total nitrogen (N), %	0.072	Low	0.074	Low
4	Mobile nitrogen (N–NO_3), mg/kg	71.5	High	68.0	High
5	Total phosphorus (P), %	0.165	Moderate	0.160	Moderate
6	Mobile phosphorus (P_2O_5), mg/kg	19.0	Low	–	Low
7	Total potassium (K), %	0.54	Very low	0.57	Very low
8	Mobile potassium (K_2O), mg/kg	178.2	Low	240.8	Moderate

3.4. Plant Growth and Yield

Rosa canina plants reached heights of 1–3 m under field conditions. Fruit production ranged from 800 to 1500 fruits per plant.

Total yield ranged from 5.0 to 6.0 t/ha across studied sites (Table 4).

Table 4. Effect of TERIA-S biofertilizer on Rosa canina productivity

Parameter	Control (no treatment)	TERIA-S treatment	Change (%)
Plant height (m)	1.0–2.5	1.5–3.0	+10–15
Fruits per plant (no.)	800–1200	1000–1500	+12–20
Yield (t/ha)	5.0–5.4	5.6–6.0	+8–12
Fruit weight (g/fruit)	1.5–2.3	1.8–2.6	+10–15
Biomass (overall)	Moderate	Increased	qualitative improvement

3.5. Effect of Biofertilizer Application

Application of TERIA-S biofertilizer increased yield by 8–12% compared to the control. Treated plants showed improved vegetative growth and better leaf development.

Discussion

The results of this study demonstrate that Rosa canina L. cultivation in the Bukhara region is strongly influenced by combined effects of soil salinity, alkalinity, and nutrient limitations. The recorded electrical conductivity values (5.20–8.12 dS/m) indicate that the studied soils are under persistent salt stress, which is a common characteristic of arid agroecosystems in Central Asia. Similar salinity levels have been reported to significantly reduce plant water uptake and suppress physiological activity in perennial crops [14].

The dominance of chloride and sulfate salts suggests that osmotic stress is the primary limiting factor for plant development in the studied area. Under such conditions, plants experience reduced root hydraulic conductivity, which directly affects nutrient absorption and biomass accumulation. This explains the moderate productivity (5.0–6.0 t/ha) observed in Rosa canina plantations.

Despite relatively high total concentrations of macroelements (Ca, K, Mg, Fe), their bioavailability remains limited due to calcareous and alkaline soil conditions. The formation of insoluble compounds such as calcium phosphates and potassium aluminosilicates reduces nutrient

accessibility to plants. This phenomenon has been widely documented in calcareous soils and is considered a key constraint for crop production in arid environments .

The agrochemical results further confirm nutrient imbalance in the studied soils. Low total nitrogen and potassium levels, combined with critically low available phosphorus, indicate an unstable nutrient supply system. Although nitrate nitrogen was relatively high, its short-term availability alone is insufficient to sustain long-term productivity without continuous replenishment.

Soil salinity and nutrient deficiency act simultaneously, creating a combined stress environment that limits both vegetative growth and reproductive development of Rosa canina. In addition, high pH conditions further reduce micronutrient solubility, particularly iron and zinc, which are essential for enzymatic and metabolic processes . These combined constraints directly affect fruit formation and yield stability.

The application of microbiological biofertilizer TERIA-S demonstrated a positive effect on plant productivity, with yield increases of 8–12% compared to the control. This improvement can be attributed to enhanced microbial activity and increased solubilization of immobilized nutrients. Beneficial microorganisms in the biofertilizer likely contributed to the release of phosphorus and potassium from insoluble mineral forms, improving their availability to plants.

In addition, microbial activity may have improved soil biological properties and root–soil interactions, leading to better nutrient uptake efficiency. Under saline conditions, such biological interventions can partially alleviate stress effects by improving root development and enhancing plant tolerance to osmotic imbalance. Similar positive effects of microbial inoculants on plant growth under salinity stress have been reported in previous studies [15].

The findings of this study suggest that soil salinity alone is not the only limiting factor; rather, the interaction between salinity, alkalinity, and nutrient immobilization determines the overall productivity of Rosa canina. Therefore, improving soil fertility requires an integrated approach combining salinity management with biological and nutrient-based interventions.

The soils of the “Shuxrat” farm are characterized by moderate humus levels but low total macronutrient reserves, particularly nitrogen and potassium, along with critically low available phosphorus. Although nitrate nitrogen was relatively sufficient, an imbalance between total and mobile nutrient forms indicates an unstable nutrient supply system.

These results suggest that soil fertility in the studied area is limited not only by nutrient deficiency but also by inefficient nutrient transformation processes. Without targeted soil fertility management, including organic matter improvement and balanced phosphorus–potassium supplementation, long-term productivity of Rosa canina may remain constrained under existing field conditions.

Overall, the results indicate that microbiological biofertilizers such as TERIA-S represent a promising sustainable strategy for improving soil fertility and enhancing the productivity of medicinal plants under arid conditions. However, long-term field studies are necessary to fully evaluate their impact on soil microbial dynamics, nutrient cycling, and phytochemical composition of Rosa canina.

Conclusion

The present study demonstrates that Rosa canina L. cultivation in the Bukhara region is significantly constrained by soil salinity, alkalinity, and nutrient imbalance. The analyzed soils were characterized by moderate to strong salinity (ECe 5.20–8.12 dS/m) and slightly alkaline reaction (pH 7.6), which together reduce nutrient availability and limit plant performance.

Although soils contained relatively high total amounts of macroelements, the availability of essential nutrients, particularly phosphorus and potassium, was low due to chemical fixation processes in calcareous conditions. This imbalance was reflected in the moderate productivity of Rosa canina plantations (5.0–6.0 t/ha).

The application of microbiological biofertilizer TERIA-S showed a positive effect on plant productivity, increasing yield by 8–12% and improving plant growth characteristics. This suggests that microbial inoculation can partially alleviate the negative effects of salinity and nutrient limitations by enhancing nutrient solubilization and improving soil biological activity.

Overall, the study confirms that improving soil fertility through integrated management strategies, including the use of biofertilizers, is essential for sustainable cultivation of Rosa canina under arid conditions. These findings provide practical implications for enhancing medicinal plant productivity in saline and nutrient-limited soils of Central Asia.

DECLARATION

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Conflict of Interest

The author declares no conflict of interest.

Author Contributions

Atoeva D.O. is the sole author of this manuscript and was responsible for all aspects of the study, including conceptualization, methodology, fieldwork (soil sampling), laboratory analysis, data curation, formal analysis, interpretation of results, and writing of the manuscript.

Data Availability Statement

All data generated or analyzed during this study are included in this published article. Additional data are available from the author upon reasonable request.

Ethical Approval

This study did not involve human participants or animals. Therefore, ethical approval was not required. The research was based solely on soil sampling and laboratory physicochemical analyses.

Consent for Publication

The author confirms that this manuscript is original, has not been published previously, and is not under consideration by any other journal. The author agrees to its submission and publication in Journal of Applied Ecology and Environmental Design.

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