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Some Soil Chemical Properties at Different Depths in the Inner and Outer of the Plant Canopy of Russian Thistle

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A R T I C L E   I N F O

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A B S T R A C T

This study was carried out to determine the acidity (pH), electrical conductivity (EC), lime, organic matter (OM), nitrogen (N), calcium (Ca), potassium (K), magnesium (Mg), sodium (Na) and phosphorus (P) contents at different soil depths in the inner and outer of the plant canopy of Russian thistle (*Salsola ruthenica* Iljin) growing under the ecological conditions of Iğdır province. The study was conducted in 2023 according to the split-plot experimental design with three replications. According to the research results, it was observed that there were significant differences in pH, lime, calcium, potassium and magnesium contents in the soils taken from inner and outer the plant canopy Compared to the soils taken outer the canopy, the pH value and calcium content of the soils taken inner the canopy were lower, while the lime, potassium and magnesium contents were higher. Significant changes were observed in the EC, nitrogen, calcium, potassium, magnesium and sodium contents of the soils taken from different depths. The highest EC value and calcium content were determined at 0-20 and 20-40 cm soil depth. Nitrogen content was determined at 0-20 and 40-60 cm soil depth, potassium and sodium contents were determined at 40-60 cm soil depth, and magnesium content was determined at 20-40 cm soil depth.

1. Introduction

The factors affecting soil formation are diverse and complex in their interactions and have caused the formation of areas with different levels of soil properties on the earth's surface. In addition, the biological, chemical and physical properties of the soil may change due to biological and geological or anthropogenic activities (Zúñiga et al., 2019). The chemical differences that these changes cause in the soil depth are very important for the development of plants. Soil depth provides more mechanical support to the plant as well as more water and nutrients to the plant (Rajakaruna & Boyd, 2008). Therefore, the changes that occur along the soil profile in the inner canopy of plants growing in semiarid and arid areas are of great importance for the formation of productive areas. Many chemical reactions that affect plant nutrient availability have also been reported to affect soil pH (Schoenholtz et al., 2000). The presence of sufficient amounts of suitable plant nutrients in the soil, the organic matter, texture, structure, pH and EC value of the soil are factors that significantly affect the fertility of the soil. At the same time, these factors are indicators of obtaining healthy food from the soil and the health of humans and animals (Papendick & Parr, 1992; Doran & Parkin, 1994).

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Considering all these, practices that will contribute to soil fertility are of great importance. In areas with arid and desert ecosystems, vegetation has important contributions to soil properties. The vegetation cover and overgrazing of plants in these areas have three important effects on both the distribution of vegetation and soil properties. The first of these is the change in vegetation cover following overgrazing, the second is the contributions to the soil by increasing the number of plants in the area, and the third is the benefits to the soil and ecosystem as a result of the expansion of plant-covered areas (Zheng et al., 2008).

Russian thistle is used fresh as a salad by humans and as feed for sheep and goats. It is also used in various treatments in the field of health; it is effective against bee and insect stings (Moerman, 1998). This plant is common in forests, roadsides, deserts, poorly managed meadows and pastures, and can grow in areas up to 1750 meters in altitude (Dimen, 2016). This plant, which is adapted to regions with dry summers and cold winters, is more common in semi-arid areas (Mosyakin, 1996). It is widespread in Asia, Europe and North Africa, and is also found in North America and Australia (Wagner et al., 1990). If appropriate plant selection and land management are not made in semi-arid and arid climate regions, it leads to sparse vegetation and increased soil and water losses (Temel & Keskin, 2019).

There is very limited research on how Russian thistle affects the soil structure in the areas where it grows. This research was carried out to determine some chemical (pH, EC, lime, organic matter, N, Ca, K, Mg, Na and P) contents at different soil depths in the inner and outer of canopy areas of russian thistle.

2. Materials and Methods

This study was carried out in the wind erosion area located within the borders of Iğdır province, where marginal soil and climate conditions are effective. When we look at land use, 50.5% (6,842 ha) of the erosion area is used as 2nd class pasture and 49.5% (6,700 ha) is used as heathland (Sevim, 1999). In addition, 80.7% (5,524 hectares) of the existing pasture areas face the problem of stoniness (Demir & Keskin, 2016). The district of Aralık has an average altitude of 825 meters and covers a total area of 13.542 hectares (Özdoğan, 1976).

The research was carried out in randomized blocks with three replications according to the factorial experimental design in 2023. Soil samples were taken from 0-20, 20-40 and 40-60 cm soil depths in the inner/outer of canopy of 5 randomly selected russian thistles in each block.

The pH value in these soil samples was measured with a glass electrode pH meter using a 1:2.5 soil-water mixture (Sağlam, 1994). Electrical conductivity (EC dS m-1) in the filtrates obtained from saturation mud was determined with an electrical conductivity device (Rhoades, 1982). The amount of lime ($CaCO_3$) was determined as a percentage with the Scheibler Calcimeter method (Nelson & Sommers, 1982). Organic matter (OM) content was determined with the Smith-Weldon technique (Nelson & Sommers, 1982). Nitrogen (N) content was determined with the micro Kjeldahl method by applying the wet digestion method with a mixture of salicylic acid and salt (Bremner & Mulvaney, 1982). Exchangeable cations (Na, Ca, K and Mg) were obtained by sodium acetate (1 N, pH = 8.2) and then the solutions were extracted with ammonium acetate (1 N, pH = 7.0) and then read using the ICP-OES device (Rhoades, 1982). Phosphorus content was determined using the blue color method of phosphorus soluble in acid fluoride (Sağlam, 1994).

Variance analyses of the data were performed using the JMP 5.1.0 statistical package program according to the factorial experimental design in randomized blocks, and the grouping of significant means was performed according to the LSD test.

3. Results and Discussion

In this study, which was carried out to determine the EC, pH, organic matter, lime, nitrogen, calcium, sodium, magnesium, potassium and phosphorus contents of soils taken at different depths (0-20, 20-40 and 40-60 cm) and inner/outer of plant canopy, the variance analysis results are presented in Table 1. Among the soil samples taken from the inner and outer of the canopy, lime, calcium, potassium and magnesium contents were found to be statistically significant at $p<0.01$, and soil pH was found to be statistically significant at $p<0.05$ (Table 1.). EC, organic matter, nitrogen, sodium and phosphorus contents of the soils taken from the inner and outer parts of the canopy were found to be insignificant. According to soil depths, EC, calcium, potassium and sodium contents showed significant differences at $p<0.01$, and nitrogen and magnesium contents at p<0.05 probability level. On the other hand, it was determined that there were no significant changes in pH, lime, organic matter and phosphorus contents depending on soil depth.

It was determined that the pH values, lime, calcium, potassium and magnesium contents of the soil inner and outer of the canopy of Russian thistle varied between 7.93-8.19%, 8.39-10.81%, 4.33-5.24%, 0.21-0.44% and 0.32-0.44%, respectively (Table 2). Accordingly, soil samples taken from the inner parts of the canopy were found to have higher lime, potassium and magnesium contents compared to the outer parts of the canopy, while their pH and calcium contents were found to be lower. When the important parameters based on depth were examined, nitrogen (0.0028%) was found to be the highest at 0-20 cm, calcium (5.27%) and magnesium (0.41%) at 20-40 cm, EC (1.70), potassium (0.43%) and sodium (0.48%) at 40-60 cm soil depths (Table 2.).

Table 1. Variance analysis table of the examined features

Sources of Variation	F values and significance									
	pH	EC	Lime	OM	N	Ca	K	Mg	Na	P
Inner/outer of canopy (C)	5.3^{*}	0.02^{ns}	11.88^{**}	0.18^{ns}	0.00^{ns}	37.44^{**}	110.36^{**}	80.01^{**}	2.82^{ns}	2.06^{ns}
Soil depth (D)	2.9^{ns}	11.91^{**}	3.06^{ns}	2.57^{ns}	4.08^{*}	55.15^{**}	24.14^{**}	5.77^{*}	12.49^{**}	2.44^{ns}
C x D int.	1.1^{ns}	1.87^{ns}	2.21^{ns}	0.86^{ns}	0.39^{ns}	41.00^{**}	18.69^{**}	10.89^{**}	3.32^{ns}	2.52^{ns}

*p < 0.05, **p < 0.01, ns: non significant

The complex interactions of plant species, atmosphere, water and biological activities in the soil cause significant changes in soil properties (Tiedemann & Klemmedson, 1973; Charley & West, 1975; Schlesinger et al., 1996; Zheng et al., 2008). As a result of the mineralization and decomposition of organic matter, elements such as magnesium, potassium and calcium in the structure of organic matter pass into the soil and increase the amount of nutrients for plants (Gençtan, 2012; Karakuş & Keskin, 2017). In addition, a study by Parlak et al. (2012) reported that total nitrogen, cation exchange capacity, available phosphorus, calcium, magnesium, potassium and sodium amounts were higher in the soils located inner the plant canopy than in the soils outer the canopy. It is observed that plants improve the physical and chemical properties of soils and make a significant contribution to their productivity.

It has been reported that the chemical and physical properties of the soil taken from different depths (0-30 and 30-60 cm) inner and outer of the canopy of *Salsola arbusculiformis* changed significantly. EC, pH, organic carbon, potassium, sodium, nitrogen and water holding capacity of the soil inner of the canopy of *Salsola arbusculiformis* were found to be higher. It has also been reported that the plant can be used impressively for the improvement of degraded pastures in desertified and arid regions (Asaadi et al., 2014). The potassium content from the data obtained in this study is consistent with the results we obtained, but other parameters were different. This may be due to different plant species and soil characteristics. In a study, it was determined that the organic matter and EC values inner of the canopy were higher than outer of the canopy. On the other hand, it was found that there was no significant difference in pH values inner and outer of the canopy (Zheng et al., 2008).

Table 2. pH, EC, N, Ca, K, Mg, Na, and P values of soils at different depths of inner/outer of the plant canopy

Soil depth (cm)	Inner canopy	Outer canopy	Soil depth Avg.	Inner canopy	Outer canopy	Soil depth Avg.
	pH (1:2.5^{-1})			EC (dS m^{-1})		
0-20	7.73	8.17	7.95	1.57	1.77	1.66 a
20-40	8.23	8.27	8.25	1.33	1.23	1.28 b
40-60	7.83	8.13	7.98	1.77	1.63	1.70 a
Inner/outer canopy avg.	7.93 b*	8.19 a		1.56	1.54	
	Lime (%)			Organic matter (%)		

0-20	8.77	8.03	8.40	0.15	0.14	0.14
20-40	12.60	8.27	10.43	0.13	0.13	0.13
40-60	11.07	8.87	9.97	0.14	0.15	0.15
Inner/outer canopy avg.	10.81 a	8.39 b		0.14	0.14	
	Nitrogen (%)			**Calcium (%)**		
0-20	0.0030	0.0027	0.0028 a	4.16 b	6.37 a	5.27 a
20-40	0.0017	0.0020	0.0018 b	4.16 b	6.15 a	5.41 a
40-60	0.0027	0.0027	0.0027 ab	4.15 b	3.20 c	3.68 b
Inner/outer canopy avg.	0.0024	0.0024		4.33 b	5.24 a	
	Potassium (%)			**Magnesium (%)**		
0-20	0.37 b	0.19 d	0.28 b	0.39 b	0.34 b	0.37 b
20-40	0.31 bc	0.21 d	0.26 b	0.47 a	0.35 b	0.41 a
40-60	0.64 a	0.22 cd	0.43 a	0.46 a	0.25 c	0.36 b
Inner/outer canopy avg.	0.44 a	0.21 b		0.44 a	0.32 b	
	Sodium (%)			**Phosphorus (%)**		
0-20	0.43	0.30	0.36 b	30.33	22.83	26.58
20-40	0.34	0.27	0.30 b	32.03	29.50	30.76
40-60	0.45	0.50	0.48 a	29.60	31.93	30.76
Inner/outer canopy avg.	0.40	0.36		30.66	28.09	

*The difference between means indicated by different letters is significant.

While the decrease in soil organic matter is very evident as depth increases inside of the canopy, it has been reported that organic matter decreases to lower amounts due to increasing depth outer of the canopy. It has been reported that EC value decreases as soil depth increases at the inner of the canopy, while EC value increases as soil depth increases at the outer of the canopy (Zheng et al., 2008). In the soil samples taken from the inner of canopy of the goat's wheat (*Atraphaxis spinosa* L.) plant, it was determined that the amount of magnesium, potassium and calcium was higher than that outer of the canopy, and the soil pH was lower. It was determined that the potassium, magnesium, sodium and phosphorus content varied depending on the depth of the soil (Karakuş & Keskin, 2017). Some properties of the soil were determined according to different soil depths (0-20, 20-40 and 40-60 cm) inner and outer of the canopy of the thorny saltwort (*Noaea mucronata*). According to the research results, it was determined that the calcium content and pH value of the soil taken from the outer of the canopy were higher than those taken from the inner of the canopy, and the potassium and magnesium content were lower. It has been determined that calcium and sodium contents vary according to soil depth (Temel & Keskin, 2019). These results support our current research. Plants play a critical role in ecosystem sustainability and soil protection. A significant amount of organic matter is added to the soil through the leaves and roots of plants. Leaves and roots added to the soil contribute to the improvement of soil structure (Demir & Keskin, 2016). In addition, plants improve the physical and chemical balances of the soil as well as its biological structure (Parlak et al., 2012).

While calcium, potassium and magnesium contents were significant at $p<0.01$ level in the interaction of inner/outer of canopy x depth, examined other parameters were found to be insignificant (Table 1.). Their inner/outer of canopy x depth interaction data are given in Figures 1, 2 and 3.

Calcium content was found to be slightly higher at 20-40 cm soil depth compared to 0-20 cm soil depth at the canopy inner area. However, the calcium content detected at 40-60 cm soil depth was obtained in similar amounts at 0-20 cm soil depth. On the other hand, it was determined that calcium content decreased as soil depth increased in the outer of the canopy area. This difference between the inner and outer of the canopy caused the interaction of the inner/outer of the canopy x depth to be significant (Figure 1.).

While there were no significant differences in the potassium contents of soils taken at different depths outer of the canopy, the potassium content of soils taken inner of the canopy decreased at 20-40 cm compared to the 0-20 cm soil depth, but increased again at 40-60 cm. This difference between the inner and outer of the canopy caused the interaction of the inner/outer of the canopy x depth to be significant (Figure 2.).

It was determined that there was no significant change in the magnesium content of the soil at 20-40 cm soil depth compared to 0-20 cm soil depth outer of the canopy, while there was a significant decrease in the magnesium content at 40-60 cm soil depth. On the other hand, there was an increase in magnesium content at 20-40 cm soil depth compared to 0-20 cm soil depth of the inner of the canopy, but this increase did not continue at 40-60 cm soil depth (Figure 3.).

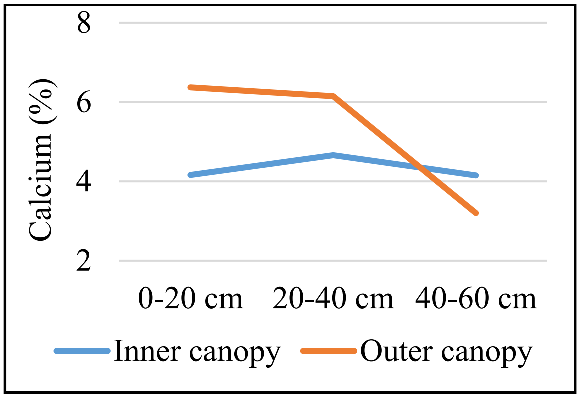

Figure 1. Changes in calcium content in the inner/outer of the plant canopy and at different depths of russian thistle

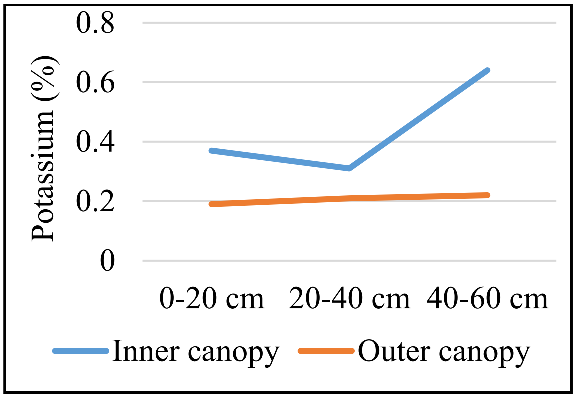

Figure 2. Changes in potassium content in the inner/outer of the plant canopy and at different depths of russian thistle

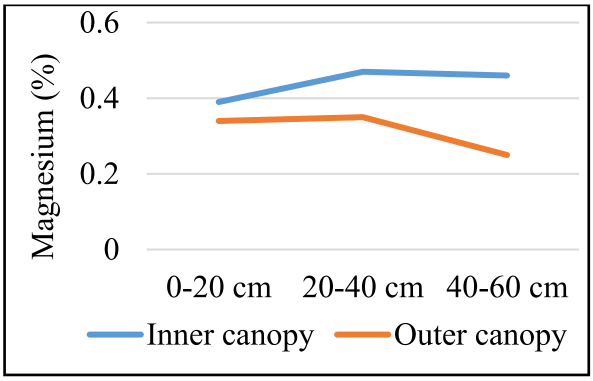

Figure 3. Changes in magnesium content in the inner/outer of the plant canopy and at different depths of russian thistle

4. Conclusion

As a result of the study, it was observed that the pH, lime, calcium, potassium and magnesium contents of the soils inner and outer of canopy of *Salsola ruthenica* differed significantly. Soil samples taken from the inner parts of the canopy were found to have higher lime, potassium and magnesium contents compared to the outer parts of the canopy, while pH and calcium contents were found to be lower. In particular, it is estimated that the decrease in soil pH at the inner of the canopy will contribute to the acidity of the soil and increase the uptake of plant nutrients in the soil. Soil EC, nitrogen, calcium, potassium, magnesium and sodium contents differed according to soil depth. While nitrogen was found to be high at 0-20 cm soil depth, calcium and magnesium were high at 20-40 cm and EC, potassium and sodium were high at 40-60 cm soil depth. In addition, calcium, potassium and magnesium were found to be significant in terms of inner/outer of canopy x depth interaction.

According to these results, it is seen that *Salsola ruthenica* can contribute to the improvement of basic soils by reducing soil pH in the canopy. It also shows that it can affect the chemical properties of the soil by increasing the percentage of lime, potassium and magnesium in the soil and decreasing the calcium.

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