POTENTIAL OF HALOPHYTE PHYTOEXTRACTION FOR SALINE SOIL REMEDIATION

BY

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Abstract

Viable agricultural land is increasingly being lost to salinity as a result of natural and anthropogenic causes. Few crops can withstand high salt levels, which is decreasing the capacity of farmers to obtain profitable yields. The availability of region-specific salt-tolerant crops has risen in recent years, although the underlying issue of salinity remains. As sodium ions increasingly become concentrated it further limits the range of crops that can be produced. The use of halophytes as a mode of phytoremediation may be an ecologically sound alternative to traditional engineering-based methods. By incorporating halophytic crops into a rotation scheme, there is potential to not only mitigate the soil but also harvest the plant matter for added revenue in market or processed into by-products.

1. Introduction

Green remediation technology has become the center of ecological rectification in regard to soil contaminants. Engineering-based methods previously dominated the domain, such as immobilization using barriers, or reduction via chemical treatments (Nouri et al. 2017). Green remediation offers a low-cost alternative that involves the use of living organisms to absorb, breakdown or neutralize toxic pollutants (Nouri et al. 2017). When such organism is a live plant, this process is known as phytoremediation. There exist six main categories of phytoremediation: (1) phytostabilization, (2) phytostimulation, (3) phytoextraction, (4) phytovolatilization, (5) phytohydraulics and (6) phytodegradation, which are exercised at varying degrees depending on the species of plant (Nouri et al. 2017). The aim of phytoremediation is to harness and debilitate pollutants surrounding the plant rhizosphere.

One mode of phytoremediation is the use of halophytic plants to assist with adverse salt levels within the upper soil horizons. Halophytes are a group of extremophiles that are characterized by their ability to thrive in saline or sodic conditions unsuitable to most plants. It is estimated that 7% of total land area around the globe is affected by salts, and that 12 million ha of irrigated agricultural land may become futile as a result of high salt content (Litalien, Zeeb 2020). The use of halophytes for desalinization was first proposed by Boyko (1966) in *Basic Ecological Principles of Plant Growing by Irrigation with Highly Saline or Sea Water* (as cited in Mirza et al. 2014). Hence, they have long been recognized for their reformative power, but it wasn't until the 21st century that the availability and usage of salt tolerant crops progressed (Nouri et al. 2017).

Research surrounding halophytic crops has flourished in recent years in response to global water shortages and increasing limitations on land. A study conducted by Rhoades (1989) focused on the reuse of drainage water by applying halophytes as a filter for salts and sulfates (Nouri et al. 2017). While independent studies on *Suaeda salsa* and *Suaeda fructicosa* have both demonstrated the ability to absorb salts from the soil and sequester them into their plant tissue (Nouri et al. 2017). Extensive research has also been focused on *Atriplex spp.* due to their widespread range across various climatic zones. In all studies, phytoremediation has been found to be an effective strategy to combat organic and inorganic pollutants in both the soil and bodies of water. In addition to being a wholesome approach to remediation, halophytes can also be harvested as a profitable crop for food, fibre and industrial purposes (Flowers, Muscolo 2015).

Although green remediation strategies are increasingly being adopted, there still exists a large knowledge gap surrounding phytoremediation and halophyte plants in general. We are aware that success is influenced by the soil, plant and environmental conditions, as well as the chemical properties of the contaminant (Nouri et al. 2017). However, if effectiveness depends on the bioavailability of the pollutant, it may take a considerable amount of time compared to engineering-based remediation methods. Additionally, it is also crucial to select the appropriate plant species for the intended outcome, as the process may be limited by rooting depth. Primary questions of concern include whether the biomass produced should be disposed of at the end of the growing season. This especially applies to halophytes that act as accumulators, as one would not want the sequestered contaminant to be re-incorporated into the soil. Furthermore, will composting be successful in breaking down the contaminants? Can certain plants be used towards animal fodder? We want to avoid the potential of animal toxicity or tainted meats entering the human food market (Nouri et al. 2017). Lastly, can the biomass be processed into usable by-products? There has been promising research regarding the production of biogas through anaerobic fermentation (Litalien, Zeeb 2020). These topics necessitate further research as recommendations are limited at this time.

The issue of soil salinity is a result of both natural and anthropogenic causes. Salts are naturally present in soil and groundwater due to the weathering of parent minerals which then become deposited via the movement of wind, water, ice or gravity (Nouri et al. 2017). The higher occurrence of salt in certain regions depends on the nature of parent bedrock, the proximity to the coast, and the variation in water table level. Those that have a low water table are subject to capillary rise of saline water, which then accumulate in the upper soil horizons (Nouri et al. 2017) (Litalien, Zeeb 2020). By the same means, frequent applications of fertilizers will also lead to a concentration of salts which may rise due to a lack of precipitation, such as in arid and semi-arid regions, or an insufficient amount of irrigation to flush the salt from the root zone (Nouri et al. 2017).

Soil salinity can be distinguished into two main groups: saline soils and sodic soils, which differ in terms of the inorganic solutes present. Saline soils are characterized by a high proportion of soluble salts, such as sodium, calcium and magnesium; whereas sodic soils are primarily dominated by sodium ions (Nouri et al. 2017) (Litalien, Zeeb 2020). Both soil categories can have adverse effects on soil structure and fertility which greatly impacts plant health and productivity. A common attribute of saline soils is water stress due to differences in soil-water potential. When there is a higher ratio of salts in the soil compared to within the roots, it reverses the osmotic gradient causing exosmosis (Nouri et al. 2017). As a result, the plant is required to expend more energy in order to extract water from the soil.

The effect of salinity is even more prominent in clay-based soils due to the stacking structure of clay platelets. The air-pockets between layers help retain water which contributes to the high-water holding capacity. As water molecules contain negatively charged oxygen atoms, they then attract the positively charged sodium ions. This leads to the swelling of clay particles and consequently the dispersion of soil colloids and destruction of soil structure (Litalien, Zeeb 2020). Plant growth is thus impaired due to limited movement of soil water and air. This restricts the cycling of nutrients between the below & above – ground ecosystems, resulting in decreased soil organic carbon (SOC). It is estimated that 3.47 tonnes per hectare of SOC have been lost from soils with increasing salinity (Litalien, Zeeb 2020).

Halophytic plants have developed numerous adaptations in order to withstand salt stress. They are generally quick growing with long root systems for water extraction and produce a significant amount of biomass (Nouri et al. 2017). Halophytes often differ in their mechanisms of salt tolerance, whether it be molecular, physiological or ecological. For example, the thick cuticle and small leaf surface area of *Salicornia spp.* help combat water loss through evaporation, while the roots are surrounded by a layer of oxygen to reduce the impact of salts (Nouri et al. 2017). It has also been observed that many halophytic species contain enlarged vacuoles which enables them to sequester higher volumes of salts (Litalien, Zeeb 2020). By continuously adjusting their osmotic gradient in response to surrounding ions, they are able to prevent the effects of sodium toxicity (Nouri et al. 2017).

This study aimed to divulge the potential of phytoextraction by the halophyte *Salsola komarovii.* It focused on the capacity of salt accumulation and sequestration into its plant tissue by analyzing the effects of increasing salinity on the rate of soil electroconductivity and plant biomass. *S. komarovii* is an obligate halophyte under the family Chenopodiaceae (Amaranthaceae) which also includes common garden vegetables such as spinach and quinoa (Mirza et al. 2014). Obligate halophytes are a group of plants that rely on moderate – high salt levels for growth (Litalien, Zeeb 2020). They are most often found in mangroves, marshes and other coastal environments. The Lower Mainland region of British Columbia is geographically constrained and thus much of the farmland is in close proximity to the Pacific Ocean. Areas further in-land may still experience a high water-table or seasonal flooding by saline waters. Furthermore, the mild climate of the region facilitates year-round soil-based crop production, often with the assistance of high tunnels for season extension, which are prone to salt accumulation. *Salsola komarovii* may demonstrate the beneficial role that halophytes can play in regional soil remediation.

A salinity gradient was formed using various depths of spent- mushroom compost in order to compare the proportion of salt ion uptake between the salt-tolerant halophyte (*Salsola komarovii)* and salt- sensitive glycophyte (*Phaseolus vulgaris*). The mushroom compost obtained is considered spent as it is the residual waste from the spawning, casing and harvesting phase (Phase 3) of mushroom production (Dodds 2019) (Robinson et al. 2018). Although less nutrient-dense than the finished compost acquired after Phase 2, the matter still contains a high proportion of macronutrients and soluble salts such as calcium, magnesium, potassium and sodium. The degree of salt uptake not only depends on the species of plant and the ratio of salts, but also on the osmotic gradient surrounding plant vacuoles. For example, Na+ ions are more effective at the function of osmotic adjustment when compared to K+ ions (Ramos et al. 2004). This is due to the plants ability to maintain their internal sodium plus potassium concentrations, which is partly influenced by the lack of centralized control systems for the regulation of K+ ions (Matoh et al. 1986).

It was presumed that *S. komarovii* would out-perform *P. vulgaris* in all aspects of the experiment. This is primarily based on the different mechanisms of abiotic stress tolerance between halophyte vs. non-halophyte plants. A general gauge of halophytism is the capacity of the plant to complete its lifecycle under NaCl concentrations exceeding 200 mM (Mirza et al. 2014). This is significantly greater than the threshold for most plants of 40 mM (Bayuelo-Jimenez et al. 2012). Once the peak level is met, signs of salt stress may become visible.

2. Objectives

- Determine the capacity of salt uptake by *Salsola komarovii* as a means of saline soil remediation

1. Compare the difference over time in soil electroconductivity between a halophyte (*Salsola komarovii)* and glycophyte (*Phaseolus vulgaris).*
2. Study variation in plant growth with an increasing ratio of mushroom compost.
3. Explore the relationship between increasing salinity and biomass in order to determine if halophyte development is correlated to salt content.

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3. Methods

3.1 Experimental design:

Seeds were obtained from West Coast Seeds for both *Salsola komarovii* and *Phaseolus vulgaris.* Seeds were started indoors at the end of May before being transplanted to the field. A randomized complete block split-plot design was formed, with 4 blocks each measuring 2m x 8m, divided into 16 plots of 2m x 2m and 64 sub-plots measuring 1m x 1m. The large number of sub-plots is due to three separate student research projects involving mushroom compost all being conducted simultaneously at the same research site (*a technical adjustment due to the Covid-19 pandemic).* Each plot was randomly assigned a treatment of mushroom compost which varied in depth from 0 cm (control), 5 cm, 10 cm and 20 cm.

Spent mushroom compost (SMC) was obtained from Highline Mushrooms. This facility incorporates the following raw materials into the compost: chicken manure, gypsum ($CaSO_4$), and wheat straw saturated with “goody water”, a nutrient and microorganism rich water that is collected from prior processing steps (Dodds 2019). The mushroom compost was sourced from two separate lots and analyzed by Exova Laboratory (*now Element Laboratory*). The compost was combined and mixed into a cohesive unit before field application.

	Highline Mushroom Lot ID 1302554	**Highline Mushroom Lot ID 1284087**
Organic matter	56.9%	41.3%
pH	6.6	7.2
Electrical conductivity	12.9 dS/m	7.27 dS/m
Nitrogen (N)	130 ppm	320 ppm
Phosphorus (P)	1600 ppm	640 ppm
Potassium (K)	25900 ppm	10800 ppm
Sodium (Na)	675 ppm	438 ppm

Table 1. Analysis of available nutrients, soil acidity, and aggregate organic constituents obtained from Exova Laboratory on Highline Mushroom compost, lot ID 1302554 and ID 1284087.

Transplants were set to the field on June 19th, 2020 where they remained until completion of the experiment. Each sub-plot received two transplants of *P. vulgaris* or *S. komarovii*. In order to mitigate the chance of salt toxicity to the young plants, a small pocket was formed within the compost which enabled the transplants to be set in direct soil. Data collection commenced 2- weeks after field transplanting and continued on a bi-weekly basis over a 10-week period. The plots were regularly maintained throughout this period which included routine irrigation and weed removal.

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3.2 Data collection:

Electroconductivity

Soil electroconductivity (EC) was measured using an electroconductivity meter, which gives a measure (mS/cm) of salinity via the rate of electrical current passing through a concentration of ions. The faster the electrical current, the higher the concentration of ions. Mushroom compost was pulled away from the base of the plant to allow full soil-contact with the EC meter probes. Data was collected on a bi-weekly basis from the transplant date.

Biomass

Biomass is synonymous with plant health in terms of overall plant weight. Fresh weight was measured upon completion of the experiment by cutting *Salsola komarovii* at the soil level and harvesting mature pods of *Phaseolus vulgaris.*

3.3 Statistical analysis:

All data was analyzed using jamovi software.

Electroconductivity

A linear mixed-model approach was utilized to analyze soil electroconductivity data. This method was chosen due to the data being collected from each treatment plot at regular intervals throughout the 10- week period of the experiment. The fixed effects were crop type and depth of mushroom compost mulch, while the random effect was considered in terms of soil spatial variability between treatment plots.

Biomass

Plant biomass was analyzed using a regression analysis, with the independent variables of crop type and depth of mushroom compost mulch, and the dependent variable as plant growth measured as fresh-weight in kilograms.

4. Results

Electroconductivity

A noticeable effect was observed on soil electroconductivity at different depths of spent mushroom compost. Soil electroconductivity increased with compost depth for both *Salsola komarovii* and *Phaseolus vulgaris* (Fig 4.1). The most significant difference ($P \leq .05$) between treatments occurred at SMC depths between 0 cm – 5 cm; 0 cm – 10 cm; 0 cm – 20 cm, as well as between 5 cm – 20 cm, and 10 cm – 20cm, as displayed in Table 2. No significant effect was observed at all other treatment levels.

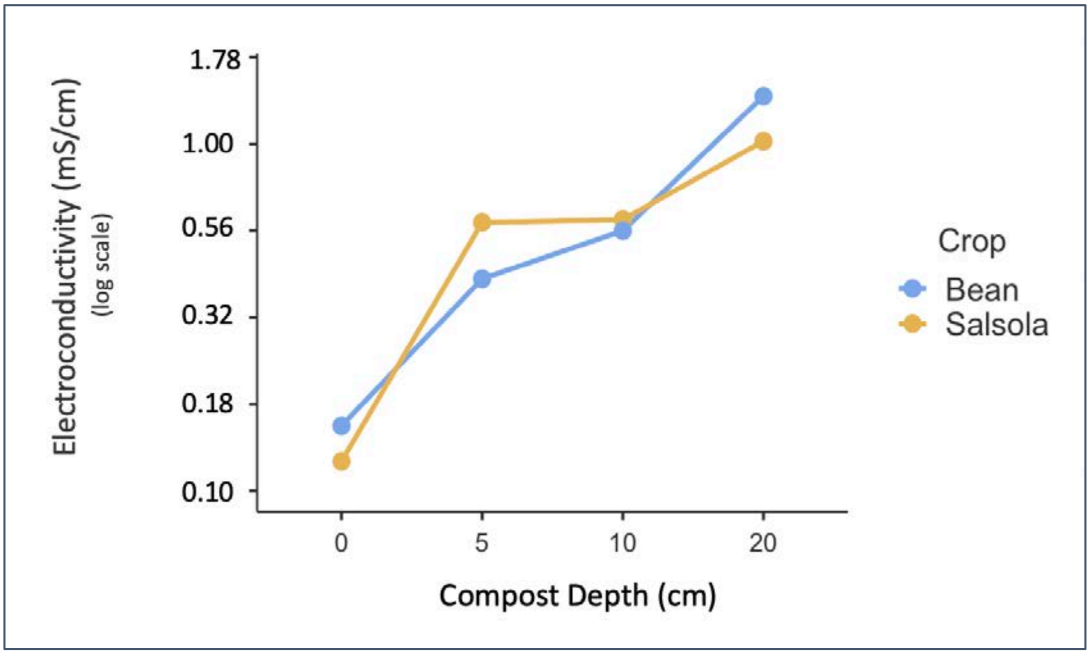

Figure 4.1 Effect of increasing depth of spent mushroom compost on soil electroconductivity (mS/cm) for *P. vulgaris* and *S. komarovii*. Each value represents the mean of 4 replicates.

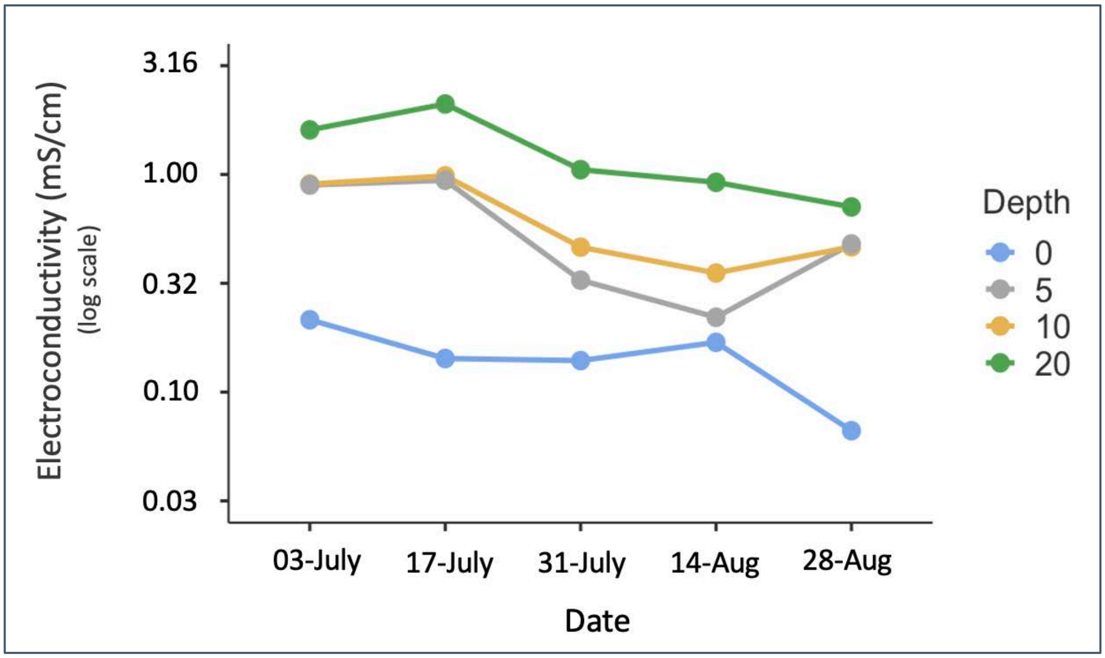

Figure 4.2. Effect of 0, 5, 10, and 20 cm spent mushroom compost on soil electroconductivity (mS/cm) over 10- weeks of treatment for *P. vulgaris* and *S. komarovii*. Each value represents the mean of 4 replicates.

The change in soil electroconductivity over 10 weeks of salt treatment is displayed in Figure 4.2. This illustrates the mean rate of electroconductivity for both crops at each treatment level. There was a significant ($P \leq .05$) interaction between SMC depths 0 cm – 5 cm, and 0 cm – 10 cm from July 3rd to August 14th, 2020. However, the interaction between crop – depth – date was not significant ($P \leq .001$), indicating that both crops responded similarly to the different rates of mushroom compost mulch throughout the duration of the experiment. There was no significant (P ≤ .05) crop effect on soil electroconductivity at each treatment level. The distinction arose from the interaction between crop – depth, namely between the control and salt treatments (Fig 4.3).

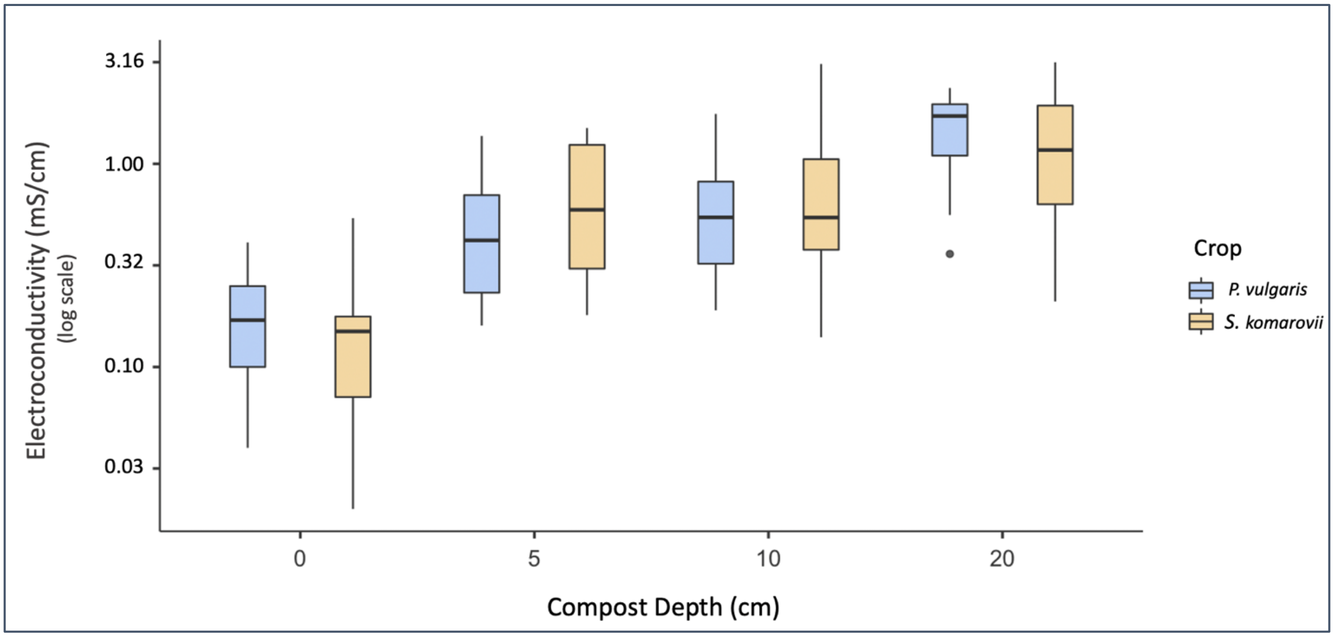

Figure 4.3. Boxplot of soil electroconductivity (mS/cm) for the four experimental conditions planted with *P. vulgaris* and *S. komarovii*. Median values are represented by the central horizontal line. Vertical whiskers represent the upper and lower quartile range

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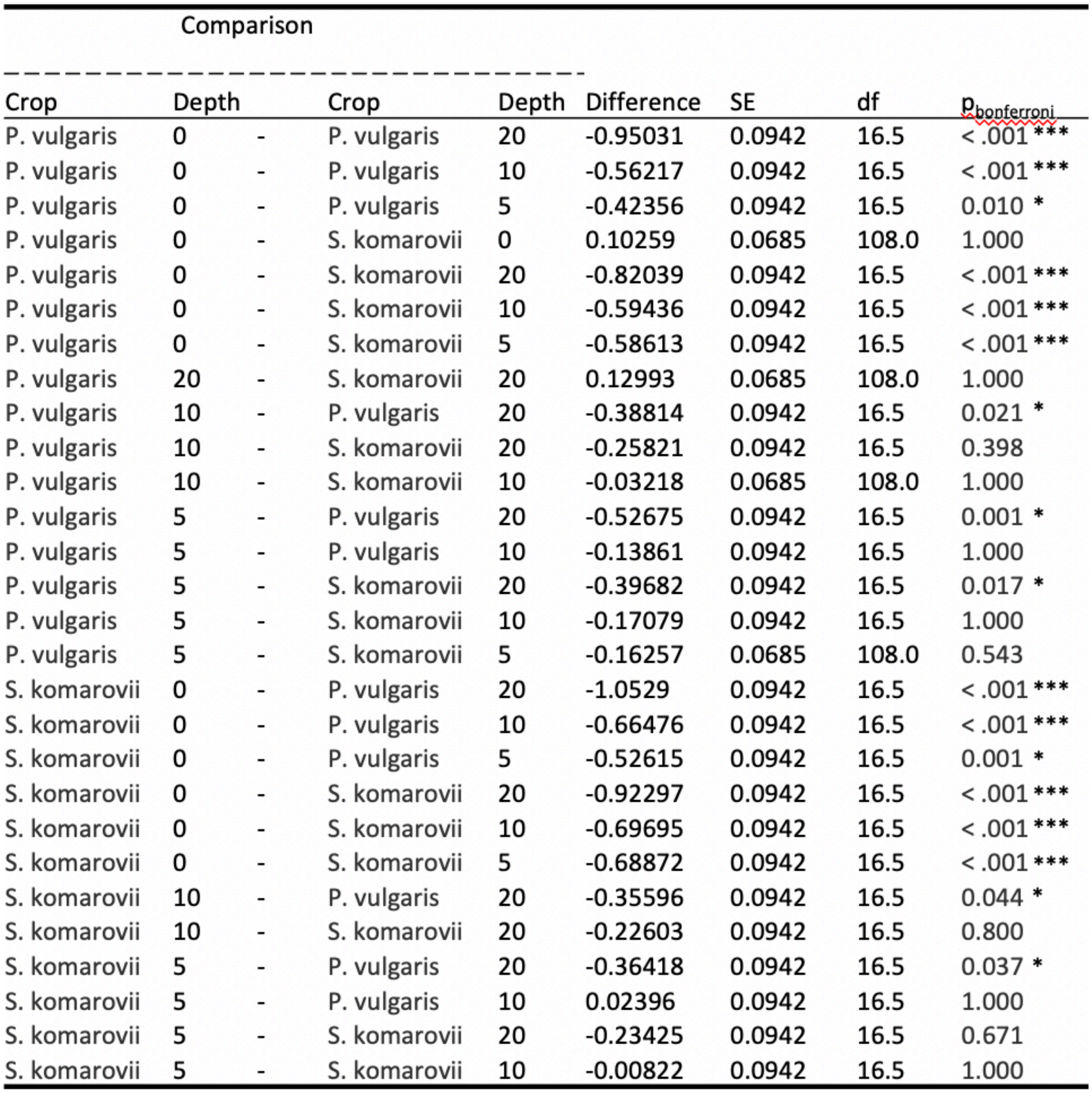
Table 2. Post hoc comparison of *P. vulgaris* and *S. komarovii* at each level of spent mushroom compost.



Comparison								
Crop	Depth		Crop	Depth	Difference	SE	df	$p_{bonferroni}$
P. vulgaris	0	-	P. vulgaris	20	-0.95031	0.0942	16.5	< .001 ***
P. vulgaris	0	-	P. vulgaris	10	-0.56217	0.0942	16.5	< .001 ***
P. vulgaris	0	-	P. vulgaris	5	-0.42356	0.0942	16.5	0.010 *
P. vulgaris	0	-	S. komarovii	0	0.10259	0.0685	108.0	1.000
P. vulgaris	0	-	S. komarovii	20	-0.82039	0.0942	16.5	< .001 ***
P. vulgaris	0	-	S. komarovii	10	-0.59436	0.0942	16.5	< .001 ***
P. vulgaris	0	-	S. komarovii	5	-0.58613	0.0942	16.5	< .001 ***
P. vulgaris	20	-	S. komarovii	20	0.12993	0.0685	108.0	1.000
P. vulgaris	10	-	P. vulgaris	20	-0.38814	0.0942	16.5	0.021 *
P. vulgaris	10	-	S. komarovii	20	-0.25821	0.0942	16.5	0.398
P. vulgaris	10	-	S. komarovii	10	-0.03218	0.0685	108.0	1.000
P. vulgaris	5	-	P. vulgaris	20	-0.52675	0.0942	16.5	0.001 *
P. vulgaris	5	-	P. vulgaris	10	-0.13861	0.0942	16.5	1.000
P. vulgaris	5	-	S. komarovii	20	-0.39682	0.0942	16.5	0.017 *
P. vulgaris	5	-	S. komarovii	10	-0.17079	0.0942	16.5	1.000
P. vulgaris	5	-	S. komarovii	5	-0.16257	0.0685	108.0	0.543
S. komarovii	0	-	P. vulgaris	20	-1.0529	0.0942	16.5	< .001 ***
S. komarovii	0	-	P. vulgaris	10	-0.66476	0.0942	16.5	< .001 ***
S. komarovii	0	-	P. vulgaris	5	-0.52615	0.0942	16.5	0.001 *
S. komarovii	0	-	S. komarovii	20	-0.92297	0.0942	16.5	< .001 ***
S. komarovii	0	-	S. komarovii	10	-0.69695	0.0942	16.5	< .001 ***
S. komarovii	0	-	S. komarovii	5	-0.68872	0.0942	16.5	< .001 ***
S. komarovii	10	-	P. vulgaris	20	-0.35596	0.0942	16.5	0.044 *
S. komarovii	10	-	S. komarovii	20	-0.22603	0.0942	16.5	0.800
S. komarovii	5	-	P. vulgaris	20	-0.36418	0.0942	16.5	0.037 *
S. komarovii	5	-	P. vulgaris	10	0.02396	0.0942	16.5	1.000
S. komarovii	5	-	S. komarovii	20	-0.23425	0.0942	16.5	0.671
S. komarovii	5	-	S. komarovii	10	-0.00822	0.0942	16.5	1.000

(*) and (***) denote differences at $p \leq .05$ and $p \leq .001$, respectively (Bonferroni test).
SE= standard error; df= degree of freedom.

Biomass

Biomass was evaluated in terms of fresh weight as an indicator of plant health. Both *Phaseolus vulgaris* and *Salsola komarovii* showed a significant ($P \leq .001$) difference in fresh weight between the control and treatment plots (Fig 4.4). Although no significant ($P \leq .05$) effect was observed between the crop – depth interaction, except at the 0 cm – 5 cm level. The large distinction in fresh weight between the two crops is primarily due to physiological differences in growth. *S. komarovii* develops into an orbicular bush with extensive biomass, whereas *P. vulgaris* is a variety of bush bean that remains relatively compact. In addition, only the edible pods were harvested and weighed for *P. vulgaris* while *S. komarovii* is essentially all edible and the entire plant was cut at the soil level.

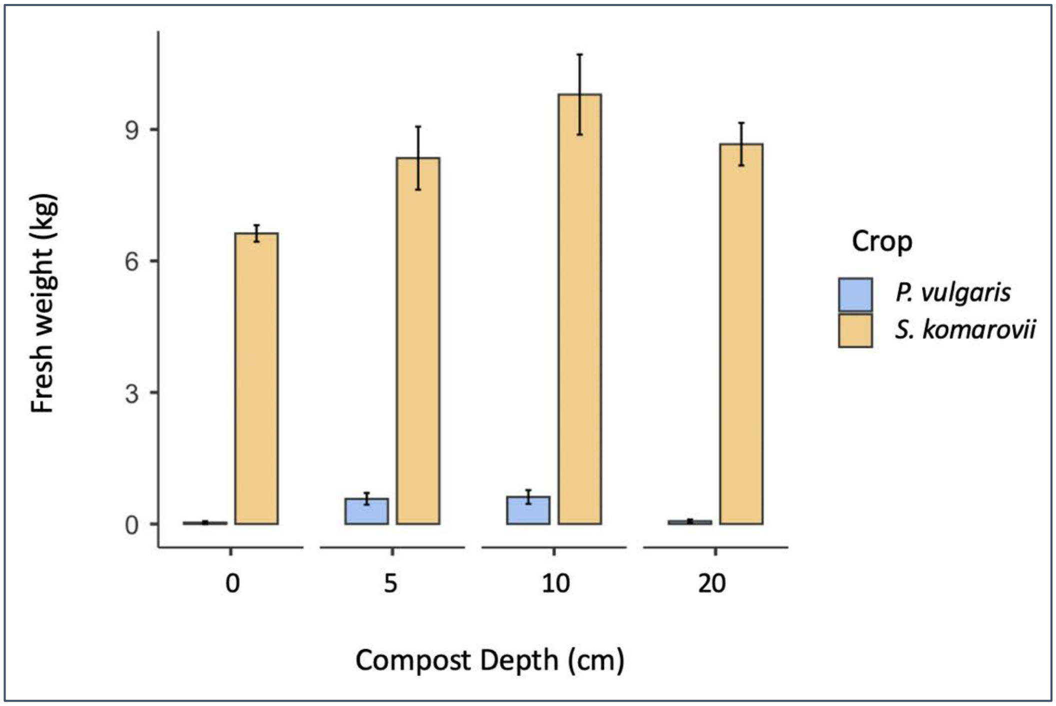


Figure 4.4. Fresh weight in kilograms at each treatment level after 10- weeks of salt treatment for of *P. vulgaris* and *S. komarovii*. Each bar represents the mean of 4 replicates.

5. Discussion

The objective of this study was to compare the difference over time in soil electroconductivity between a halophyte (*Salsola komarovii*) and glycophyte (*Phaseolus vulgaris*) and explore the relationship between increasing salinity and plant biomass. The results show that there is a significant ($P \leq .001$) difference in soil EC at different depths of spent mushroom compost, as well as a significant interaction between crop – depth, and depth – date. Although, there was no significant ($P \leq .05$) effect of crop itself or the interaction between crop – depth – date on soil electroconductivity. In terms of plant biomass measured as fresh weight, there was a significant ($P \leq .001$) difference between the control and three salinity treatment levels, however the interaction between crop – depth only saw a significant ($P \leq .05$) effect between the 0 cm – 5 cm level. For these reasons, the results of the experiment do not support the first hypothesis that soil electroconductivity would change depending on crop type (halophyte vs. glycophyte) over the course of the trial. The results also do not support the second hypothesis that plant growth of *P. vulgaris* would decline at a greater rate than *S. komarovii* with increasing salinity.

Despite the difference in salt tolerance mechanisms between halophytic and glycophytic species, the final fresh weight of *P. vulgaris* followed the same trend as *S. komarovii* of increasing with salinity, to a certain threshold. Figure 5.1 illustrates the relationship between salinity and relative growth of halophytes and different classes of glycophyte. Halophytes generally experience greater productivity with increasing salt levels, whereas glycophytes are considered salt sensitive and would have a negative yield response at salinity levels over 2 dS/m^{-1} (Bayuelo-Jimenez et al. 2012). However, previous research conducted by Bayuelo-Jimenez et al. (2003) found that certain *Phaseolus* species, including *P. vulgaris*, have the ability to limit the absorption of Na+ ions in their roots and leaves, and may therefore be classified as a salt-tolerant glycophyte. The salt tolerance of certain *Phaseolus* species has been associated with improved stomatal control, where tissue osmotic potential can be adjusted in response to the concentration of inorganic ions (Bayuelo-Jimenez et al. 2003).

In addition to the possible superior salt tolerance of *Phaseolus* species, the unanticipated growth pattern from this trial may also be contributed to a confounding intercrop effect, due to both plant species being situated within the same 1 x 1m plot. Separate studies on intercropping halophytes with non-halophyte crops saw beneficial results. Graifenberg et al. (2003) studied the effects of Na+ uptake by greenhouse tomatoes when intercropped with *Salsola soda*. They found that the tomatoes absorbed fewer Na+ ions while also increasing phosphorus and calcium uptake. Albaho & Green (2000) also intercropped greenhouse tomatoes with *Sueda salsa* and found similar results of decreased Na+ concentrations within the plant tissue and growing medium (Simpson et al. 2018). Although the intercropping variable was not tested during the course of this experiment, these studies prove that halophyte species have an influence on the rhizosphere of surrounding plants.

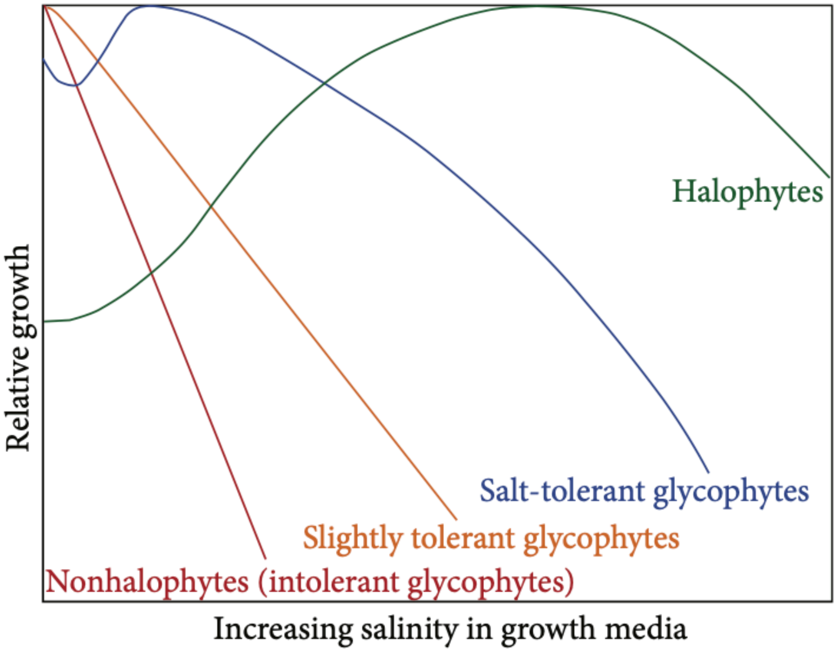


Figure 5.1 Schematic of relative growth with increasing salinity for different classifications of salt tolerance. *Note*. From “Potential use of halophytes to remediate saline soils,” by Mirza et al, 2014, *BioMed Research International, vol 2014, Article ID 589341.*

Furthermore, the degree of salt uptake, as measured by changes in soil electroconductivity, does not follow the prediction that soil salinity would diminish at a greater rate with a halophyte compared to a glycophyte. The significant results stemmed from the variation in salinity provided by the different depths of spent mushroom compost. The lack of halophytic salt uptake observed in this experiment may be due to the species of *Salsola* selected, as few field experiments have been performed with *S. komarovii*. However, Shekhawat et al. (2006) conducted a similar study comparing the potential of saline soil reclamation between three different halophyte species, one of which was *Salsola baryosma*. The three species under study were sown in-field and irrigated with a class of water (C4-S4) known to have high levels of EC, pH, and SAR. Soil samples were collected from different depths at the end of the 3-month trial and analyzed for changes in the components previously mentioned. For *S. baryosma*, they found that soil EC from the 0 cm – 10 cm depth increased from 0.768 dS/m to 0.967 dS/m, whereas EC from the 10 cm – 20 cm depth decreased from 1.068dS/m to 0.697 dS/m. Still, these findings were inferior compared to the results obtained from the two other halophyte species, *Haloxylon recurvum*, and *Suaeda nudiflora* (Shekhawat et al. 2006). This indicates that although *Salsola sp.* are classified as halophytes, they may have a weaker salt absorption capacity compared to other species which is influenced by variations in morphological, physiological, and ecological adaptations.

Although *S. komarovii* and *S. baryosma* have not presented compelling results, there has been promising research with other halophytic species in the Chenopodiaceae (Amaranthaceae) family. Of these, *Suaeda sp.* and *Atriplex sp.* have been studied the most extensively. In many cases, it has been found that the extent of soil desalinization can be correlated to root density, as well as rooting depth. Trials with a higher density of halophytic plants saw better results than those with lower density, and the greatest reduction in Na+ ions occurred at soil depths over 20 cm (Al-Nasir 2009) (Shekhawat et al. 2006) (Zhao 1991). By mitigating soil toxins, crop yields may be increased as a result of improved soil structure, nutrient uptake, and water absorption which also bring subsequent financial benefits.

Overall, the flourishment of research in recent years surrounding halophytic crops as a means of green remediation has invoked interest in natural amendments. The issue of soil salinity is an ongoing obstacle that has detrimental effects on localized agriculture systems around the globe. Common remediation strategies are cost and labor intensive and necessitates new avenues that are more accessible to both developing, and agricultural-dependent developed regions. Phytoremediation by halophyte plants has potential to be an effective and ecologically sound approach to reducing the negative impacts of saline soils on agricultural crops.

6. Conclusion

Salsola komarovii is an obligate halophyte that meets the criteria of a successful salt-absorbing species by having succulent vegetative structures, producing extensive biomass, and having a long root system. Despite encompassing these features, it did not perform as anticipated which is reflected in the results. There was a significant effect ($P \leq .001$) in final fresh weight between the control and three treatment levels, however no significant ($P \leq .05$) difference was found in the ability to uptake salts from the soil when compared to the glycophyte *Phasoleus vulgaris*. Utilizing halophytes as a form of phytoremediation is still in the preliminary stage and future research will continue to reveal its feasibility under various circumstances.

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