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Effect of Potassium Humate on Soybean Germination Traits Under Salinity Stress Conditions

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ABSTRACT

Soybean is of strategic importance both as an oil crop and as a legume. Experiments have been conducted on soybean cultivation in saline soils. This study investigated the effects of salinity and K-humate concentrations on soybean germination. The findings contribute to our knowledge of soybean germination under salt stress and the potential use of potassium humate. The experiment was conducted in the laboratory of the Department of Field Crops at Adnan Menderes University, Türkiye. Seeds were surface-sterilized and placed on filter paper in Petri dishes. Different concentrations of water (control), NaCl solution (3 dS m^{-1}), and K-humate solution were added. According to the results, K-humate had a positive impact on germination rate. Significant differences were observed among control, salinity, salinity and K-humate applications. Salinity had an effect on germination and decreased the germination percentage but K-humate diminished the negative effects of salinity. These findings suggest the potential use of K-humate to enhance seedling establishment and overall plant productivity in salinity-affected environments.

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Introduction

Soybeans are one of the most significant crops worldwide due to their versatile applications in the food, feed, industrial, and health-related industries. Soybeans are a significant food source, but they are also utilized in a variety of industrial processes, such as the creation of biodiesel, plastics, and textiles. Because of their famed flexibility and plasticity, soybeans may be grown in a variety of settings and climates. As they can fix nitrogen in the soil and lessen the need for synthetic fertilizers, they are also a crucial crop for sustainable agriculture. Many nations, like the United States, Brazil, and Argentina, rely heavily on soybean exports, which are a key component of the world's food security (Fehr, WR 2007; Clemente and Cahoon,2009).

The majority of commercially important crops fall into the category of being moderately or highly susceptible to salinity. According to reports, crops have a 20–50% loss in yield as a result of salinity (Yamaguchi and Blumwald 2005). Salinity affects more than 33% of agricultural fields. According to current estimates, salinization is rising by 10% per year as a result of insufficient agricultural practices, saline irrigation water, climate change, high temperatures, and significant soil evaporation (Shrivastava and Kumar 2015). By 2050, it is predicted that salinity would damage 50% or more of agricultural fields (Jamil at all. 2011).

Osmotic stress and a lack of nitrogen delivery are problems for crops cultivated in salinity These elements severely harm plants by impairing growth, yield, photosynthesis, seed germination, and fruit quality (Murillo-Amador et al. 2007; El-Mogy et al. 2018). The early stage of growth known as the osmotic phase and the late stage of growth known as the ionic phase are when salt has an impact on plants (Munns and Tester 2008). The quantity of salt, the stage of growth, and the length of exposure all affect how plants react to it.

Soil salinity can affect germination in two ways: first, by creating an osmotic potential that prevents water uptake, and second, by the toxic effects of Na and Cl ions (Perez et al. 1998; Khajeh-Hosseini et al. 2003). According to Almansouri et al. (2001), salinity is a significant factor that either prevents or delays seed germination and seedling establishment. Researchers Munns (1993) and Bajehbaj (2010) found detrimental effects of salinity on seed germination.

Through soil (dos Santos et al. 2021) and foliar (Abdelrasheed et al. 2021) treatments, potassium humate (Kh), a salt made from humic acid (HA), is used to enhance plant growth and output. By enhancing the cell membrane's permeability, HA is thought to facilitate the passage of nutrients from the soil into the plant, hence promoting plant growth and yield (Noroozisharaf and Kaviani 2018). Additionally, it has been noted that HA promotes antioxidant enzyme activity and enhances plant growth and photosynthesis under abiotic stressors (Kaya et al. 2018). Furthermore, potassium (K) is categorized as a macroelement that is necessary for the majority of physiological activities in plants (Mridha et al. 2021). Potassium has a beneficial effect on reducing stressors such salt and drought (Kumari et al. 2021). Potassium humate increases the rate of nutrient uptake, enhances plant biomass and reduces the soil compaction (Canellas et al., 2015). Previous research has shown that HA can help crops like sorghum cope with salt stress (Ali et al. 2019). The impact of exogenous potassium humate treatment on beans has been the subject of a few research, such the one by Taha and Osman (2018), who discovered that potassium humate enhances bean development under salt stress.

This study was conducted to investigate the effects of different salt and potassium humate concentrations on germination parameters of soybeans. The findings of this study will contribute to our knowledge of soybean germination under salt stress conditions and provide insights into the potential use of potassium humate as a mitigating agent.

Material and Methods

This experiment was carried out in the laboratory of Department of Field Crops in Adnan Menderes University University, Türkiye.

The seeds of soybean were surface-sterilized with 3% Formaldehyde for 10 minutes and washed 3 times with re-distilled water. Twenty five seeds were placed Whatmann filter-paper in per Petri dish with 9 cm diameter and added 7 mL of either water (control) or NaCl solution (3 dS $m^{-1)}$ and K-humate solution (Figure 1). Research design was based on two factor-factorial randomized parcels with four replicates. The first factor was salinity; a control and 3 dS/m were used. The second factor was K-humate was used as a control, and concentration of Kh was 0.3 g L^{-1} were used.

Every day at a specific time, seed germination was recorded. When a seed's radicle had grown to a length of around 2 mm, it was considered to have germinated (Mohammadi, 2009). Radicle and plumule length were measured after 7 days. After that, seedlings were dried in an oven for 24 hours at 105°C, and the scale's precision was set to 0.001 (ISTA, 2003).

In this trial, the following agronomic characteristics were examined: fresh cotyledon weight, dry cotyledon weight, dry weight of hypocotyl, fresh weight of hypocotyl, length of hypocotyl, dry weight of roots, fresh weight of roots, root length, germination rate, germination vigor, and relative water content (RWC).

$$RWC = \frac{(\text{Fresh Weight} - \text{Dry Weight})}{(\text{Turgid Weight} - \text{Dry Weight})]} \times 100$$

Root and cotyledon plant samples were dried at 65 °C, weighed, and ground. Utilizing a microwave digestion system, concentrated HNO3-H2O2 (6:2, v/v) nitric acid (65% Merck) was used to break down dried plants. After cooling, the resultant solutions were diluted in volumetric flasks with distilled water to a maximum concentration of 50 mL. By using ICP-OES Agilent 5800 VDV, an inductively coupled plasma atomic emission spectrometer, element contents (K, Na, and P) of the final solution were determined.

Results and Discussion

In this study, character of germination rate, fresh weight of hypocotyl, dry weight of hypocotyl, length of hypocotyl, fresh weight of roots, root length, dry weight of roots, length of roots, fresh cotyledon weight, and relative water content affected significantly by salinity and length of hypocotyl affected signaficantly by K- humate. A statistically significant interaction was observed between salinity and K-humate treatments regarding the fresh weight of hypocotyl, dry weight of hypocotyl, and fresh weight of roots (Table 1).

As expected, salinity stress (3 dS/m^{-1}) reduced the germination percentage, fresh herba weight, dry herba weight, root length, fresh cotyledon weight, and relative water content of soybean plants. However, under k-humate treatment, all germination and morphological parameters increased compared to the control treatment. When comparing k-humate and salin conditions to control plants, germination rate, fresh root weight, and relative water content were in the same statistical group, while germination percentage, fresh herba weight, dry herba weight, hypocotyl length, dry root weight, root length, and fresh cotyledon weight were lower. Furthermore, there was no significant difference in the dry cotyledon weight among all treatments (Table 2).

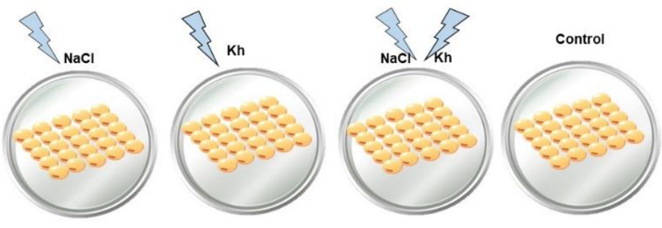

Figure 1. Scheme of the experimental treatments

Table 1. Analysis of variance for the effect of different treatments on some morphological and germination parameters of soybean seeds.

		Mean Square					
Source of Variance	df	GR	GP	FHW	DHW	FRW	DRW
Salinity (S)	1	505.01*	163.84*	0.413*	0.014**	0.072*	0.006**
K- Humade (K)	1	0.02	42.90	0.052	0.002	0.033	0.001
S and K	1	301.89*	71.4	0.233*	0.014**	0.104**	0.000
Error	12	55.311	33.35	0.047	0	0.012	0

		Mean Square				
Source of Variance	df	RL	FCW	DCW	RWC	HL
Salinity (S)	1	1.898**	10.240*	0.006	1.040*	1.630**
K- Humade (K)	1	0.334	4.818	0.007	0.129	1.247**
S and K	1	0.005	0.026	0.000	0.017	0.165
Error	12	0.085	1.33	0.015	0.160	0.042

GR: Germination rate, GP: Germination percentege, FHW: Fresh weight of hypocotyl, DHW: Dry weight of hypocotyl, FRW: Fresh weight of roots, DRW: Dry weight of roots, RL: Length of roots, FCW: fresh cotyledon weight, DCW:Dry cotyledon weight, RWC: Relative water content, HL:length of hypocotyl.

Table 2. Means of different treatments on some morphological and germination parameters of soybean seeds

Treatments	GR	GP	FHW	DHW	HL	FRW	DRW	RL	FCW	DCW	RWC
CONTROL	50.75 AB	82.50 A	0.98 B	0.15 AB	1.79 B	0.55 B	0.11 A	2.57 A	7.70 A	1.56	2.06 A
SAL	49.38 AB	75.62 B	0.90 B	0.15 AB	1.36 C	0.57 B	0.07 B	1.84 B	6.02 B	1.51	1.61 B
Kh	59.38 A	81.55 A	1.33 A	0.23 A	2.55 A	0.80 A	0.13 A	2.82 A	8.72 A	1.59	2.30 A
SAL × Kh	40.63 AB	79.37 B	0.77 C	0.11 C	1.71 C	0.50 B	0.09 B	2.17 B	7.20 B	1.56	1.73 A

+ Different letters in rows indicate differences among treatments according to LSD test ($p < 0.05$). GR: Germination rate, GP: Germination percentege, FHW: Fresh weight of hypocotyl, DHW: Dry weight of hypocotyl, FRW: Fresh weight of roots, DRW: Dry weight of roots, RL: Length of roots, FCW: fresh cotyledon weight, DCW: Dry cotyledon weight, RWC: Relative water content, HL: length of hypocotyl.

Based on the ANOM-decision charts (Figure 2), when examining the average %K content, it was found that the root had an average of 4.08, while the cotyledon had an average of 2.11. In both plant parts, the highest average was observed in the k-humate application. The average %Na content was measured as 0.44 in the root and 0.19 in the cotyledon, indicating a higher accumulation of Na in the root compared to the cotyledon. When comparing the plant parts, values above the average were obtained in both k-humate and salinity*k-humate applications. In terms of %P values, the root average (0.54) was higher than the cotyledon average (0.48). Looking at the P content in the root, values below the average were observed in the control group, while all other treatments had values above the average. In the cotyledon, below-average P accumulation was detected in the control and salinity*k-humate applications.

Salt stress reduces plant development by altering the activity of the hormones and enzymes involved in photosynthesis (Nasrallah et al. 2022) Our study shows that salinity decreased the growth of soybean seedlings. This situation can be attributed to a multitude of factors, including the ionic effect, osmotic pressure, limitations in the uptake of essential elements, a reduction in the photosynthetic rate, and Na concentrations in plant tissues (Abdeldym et al. 2020; Abbas et al. 2022). This study, Kh an salinity*kh applications increased plant germination parameters under normal and salininity conditions.

According to earlier studies that concur with our findings, Kh plays a beneficial impact in promoting soybean plant growth under both normal and salinity stress (Taha and Osman, 2018; Hemida et al. 2017, Mahdi et al. 2021). According to Hemida et al. (2017), Mahdi et al. (2021), Osman and Rady (2012), the beneficial effects of Kh on plant growth may be attributed to its capacity to increase the organic matter in growth media, make more water available, prevent mineral nutrients from leaching, and increase mineral absorption by plant roots. Additionally, this might be as a result of role of potassium in regulating various plant enzymes (Kumar et al. 2020) and humate's function as a biostimulant (Shalaby et al. 2023). Our results indicate that the most effective treatment is KH application and this result supports findings of Shalaby et al. (2023).

Salinity influences the uptake and accumulation of elements in plant tissue (Munns and Tester, 2008). In the rhizosphere, it is well known that excessive levels of Na and Cl have negative effects on the uptake of nutrients (N, P, K^+, Ca, and Mg, as well as microelements) (Abdeldym et al. 2020).

Salinity decreased the level of Na+ and raised the amount of K+ in the root and cotyledons in this investigation in Figure 2. According to a different set of findings by Saidimoradi et al. (2019), strawberry plants' K+ absorption was decreased by salinity stress.

Negative salinity conditions could be mitigated by maintaining enough K^+ levels in plants (Nadeem et al. 2019; Naeem et al. 2020; Farag et al. 2022) our results show that Na^+ content in leaves was increased in Kh and Kh * Salinity treatments (Figure 2).

Additionally, K^+ is a component in Kh, and it is known that K^+ increases salinity resistance because it competes with sodium to bind and regulate the water status of plants (Capula-Rodríguez et al. 2016). The adsorption of Na by humic substances as a result of Kh treatment aids in the reduction of Na content in common bean shoots and allows the roots to absorb more K+ (Lakhdar et al. 2009).

Salinity is the cause of osmotic stress in plants, and relative water content (RWC) in leaves is a good indicator of how well-tolerated osmotic stress is by a plant. In line with the findings of Hasanuzzaman and Fujita (2013), the current investigation found that saline stress greatly reduces the RWC content (Table 2).

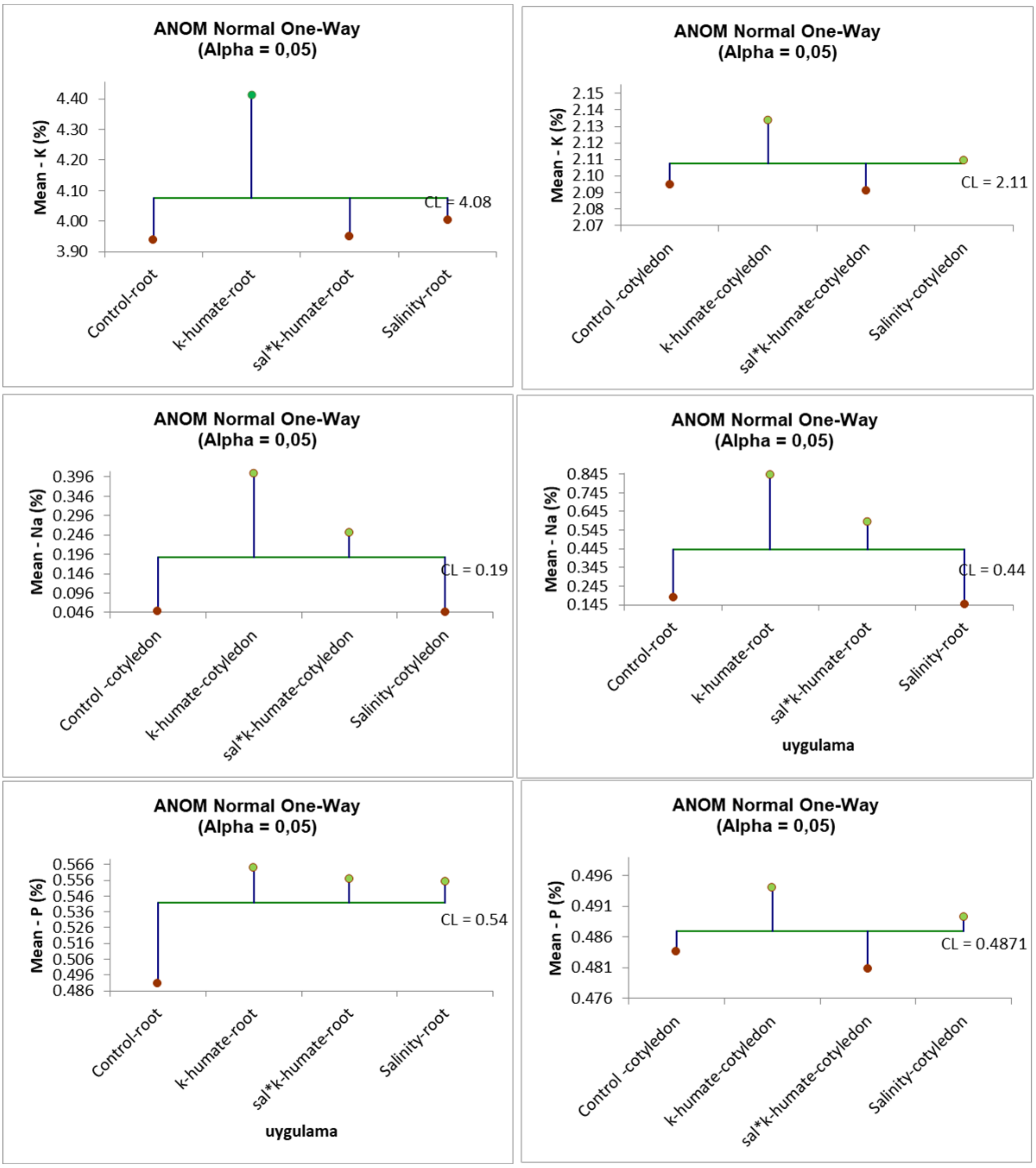

Figure 2. ANOM-decision chart with average means plant nutritients (K, Na, P, %) across root and andcotyledon (alpha > 0.05%) .Red-coloured heads represent significant deviation lower decision level and green-coloured above upper decision level from average.

(From "The Analysis of Means: A Graphical Method for Comparing Means, Rates, and Proportions," by Peter R. Nelson, Peter S. Wludyka and Karen A. F. Copeland)

However, the application of K-humate enhanced the RWC of leaves under saline conditions to a considerable extent because Kh*salinity helps to retain turgidity by reducing water loss under stress conditions (Hasanuzzaman et al., 2018).

Conclusion

Based on the results of this study, it appears that K-humate has a positive impact on germination rate. Statistically significant differences were observed among the control, salinity, and salinity * K-humate applications. When examining the FHW attribute, the K-humate application was found to have the highest positive effect compared to other treatments. The germination percentage, on the other hand, was observed to be reduced by salinity. The salinity conditions statistically decreased the germination percentage value. In terms of % Na (cotyledon), the highest measurement was recorded in the K-humate application, followed by the K-humate * salinity application. In the presence of K-humate, the negative impact of salinity on germination was mitigated, resulting in improved germination performance. These findings highlight the potential of K-humate as a beneficial factor in promoting germination under salinity stress conditions. The observed increase in germination rate suggests that K-humate application could be a promising strategy to enhance seedling establishment and overall plant productivity, particularly in salinity-affected agricultural environments.

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