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Araştırma Makalesi / Research Article

The Effect of Foliar Application of Potassium Fertilizer at Seedling Stage of Soybean Plants Under Salinity

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Abstract

Soybean is a strategically important plant with both high protein content and high oil content. Various abiotic stress conditions can be effective on agricultural activities. Practical solutions can reduce the negative effects of stress conditions. For this reason, this study aimed to investigate how soybean is affected by salinity during the seedling period and to what extent it can tolerate the negative conditions caused by this stress with potassium humate fertilizer. Arısoy soybean variety was grown in greenhouse conditions in 1.3 kg pots (sand + perlite 1:1) in a random parcel experimental design under 0, 3, 6 dS m-1 salt conditions (by applying with irrigation water) after emergence. Potassium humate (0 and 40 cc da^{-1}) was applied during the seedling period. As a result of the study, it was determined that increasing salinity conditions had significant negativelly effected on plant height, fresh and dry weight, chlorophyll a, chlorophyll b content, leaf relative water content, wheares the values leaf relative membrane permeability (RMP) of soybean plants was increased because of cell membrane demaged by oxidative stress during seedling period. In the study, although potassium humate application on soybean grown under modareted level (3dSm-1 salt) salinity conditions did not create a statistically significant difference and importance, it is recommended to carry out studies on its availability, application amount and application period since it has a positive effect on some traits (plant height, leaf area, karatoneid ve RMP) under salt stress conditions. Thus, it is thought that foliar potassium humate application will be important in terms of a practical application for producers to cope with the negative effects of salt stress conditions.

Keywords: Salinity, potassium humate, soybean, seedling stage

1.Introduction

Salinity is one of the important environmental factors limiting plant growth and development and crop yield. Salinity is the accumulation of soluble salts mixed with groundwater, especially in arid and semi-arid climatic zones, and the accumulation of salt on and near the soil surface as a result of high groundwater rising to the soil surface and evaporation (Kwiatowsky, 1998). Salinity can inhibit plant growth due to osmotic stress and ionic toxicity (Zu, 2003). The osmotic stress caused by salinity can cause a severe reduction in stomatal aperture, which in turn reduces photosynthetic capacity (Munns and Tester, 2009). Therefore, the growth status of many plants is closely related to photosynthetic activity under salt stress (Diao et al., 2014). When photosynthesis is disrupted, crop growth, development and yield are severely hampered (Nusrat et al., 2014; Bilashini et al., 2018). Salinity affects plant metabolism by reducing potential water, ion imbalance and toxicity, and CO_2 absorption in arid and semi-arid environments where it is the main factor limiting legume production (Rozema and Flowers, 2008). Salinity (Na^+), which inhibits the supply of K+ and Ca^{2+} and disrupts the efficient regulation of stomata, causes a reduction in photosynthesis and crop growth. Salinity (Na^+) inhibits K^+ and Ca^{2+} nutrition and disrupts the efficient organization of stomata, leading to reduced photosynthesis and crop growth. Cl^- toxicity also reduces photosynthetic capacity, ultimately reducing crop growth and yield (Ullah et al., 2018). Salt stress reduces germination percentage and rate, causes delayed seed germination and inhibits the viability of seed, root and shoot growth or seedling growth of plants such as legumes (Sharma, 2006). In this case, it is foliar spraying that increases organic compounds through photosynthesis and osmoregulation in crop production and reduces oxidative stress by increasing the activity of antioxidant enzymes under stress conditions (Hafez et al., 2021) Soybean plants require high levels of K fertilization (Abbasi et al., 2012). Potassium is the most abundant cation in the cytoplasm (Nelson et al., 2012). Plants that accumulate significant amounts of protein and carbohydrates in storage tissues have high K requirements. Potassium humate (K-humate) is widely used as a source of K through foliar application (Okba et al., 2021) Spraying plants with K-humate increases the permeability of plant membranes through humate application, which improves root growth, increases cell division and increases productivity (Aytaç et al., 2022). Humates are common carbonaceous materials of plant and animal residues resulting from biological and chemical decomposition (Turan et al., 2022). K^- humate is an effective natural material containing various macro elements such as N, P and K and micro elements such as Mo, Cu, Zn, B, Co and Mg (El-Hashash et al., 2022). The accumulation of chlorophyll, sugars and amino acids in plant tissues is a result of spraying plants with K-humate, which enables plants to tolerate salinity, resulting in a hormone-like effect and activation of photosynthesis, which is positively reflected in nutrient uptake, plant productivity and quality. Soybeans are an important source of protein in the human diet. Therefore, it is a valuable food, especially for vegetarians and vegans. They are also rich in healthy fats. The fats it contains are especially rich in unsaturated fatty acids and have heart-healthy effects. Soybeans are also a hardy plant in terms of salinity tolerance and are one of the preferred crops for agricultural production in saline soils. It has mechanisms to regulate water balance to combat salinity and can continue to grow and develop even under salinity. This feature enables soybean to be grown on saline soils and contributes to a more efficient use of saline soils in agriculture (Essa, 2002). The objectives of this study were; i) to examine the effects of salt stress on the early seedling development period of soybean plants, ii) to evaluate whether foliar application of potassium humate fertilizer during the early seedling development period of soybean plants grown under salinity conditions eliminates the negative effects of salt stress or alleviates the damage caused by stress.

2.Material and Methods

2.1. Material

This study was carried out under greenhouse conditions at Aydın Adnan Menderes University, Faculty of Agriculture, in 2021. Arısoy soybean variety was used as the plant material of the experiment.

2.2. Methods

Arisoy variety was grown in greenhouse conditions in 1.3 kg pots (sand + perlite 1:1) in a randomized plots experimental design. Each pot was planted with 5seed. After emergence, plants were grown under 0, 3, 6 dS m^{-1} salt conditions (by applying with irrigation water). Watering with 200 ml Hoagland solution was applied daily. When the plants reached the 3-leaf stage, potassium humate fertilizer was applied as 40 cc da^{-1}. It was applied as 1.5 cc foliar spray on the plant. After the K^- Humate was treated with foliar application, salt stress conditions were continued for another 7 days. At the end of this period, (when the plants reached the 4-leaf stage) they were harvested for measurements. Every week, the salt concentrations of the water and the pots were checked. Calculation of salt concentrations of irrigation water; We adjusted the irrigation water (Salt stress and Hoagland solution) for 120 L.

$$1dS\ m^{-1} = 10\ mM\ NaCl = 0{,}584\ g/\ 1\ lt$$

$$3\ dS\ m^{-1} = 30\ mM\ NaCl\ x\ 0.584 = 1.752\ g\ L^{-1}\ (\text{for 1 L water})$$

$$6\ dS\ m^{-1} = 60\ mM\ NaClx\ 0.584 = 3.504\ g/1lt\ (\text{for 1 L water})$$

The preparation of Hoagland Solution were made 1 L water according to Hoagland and Amon, 1950 and adjusted for 120 L water. After the emergence of the soybean plants, control and salt stress conditions was carried out by irrigated with approximately 200 mL of daily Hoagland solution and salt concentration adjusted water until the third triple leaf node.

2.3. Analysis and test methods

In this study, 3 salt stress level (0, 3, 6 dS m^{-1}) and 2 potassium humate applications [0 and 40 cc da^{-1}] were applied. The data obtained from the pot study were analyzed in the TARIST statistical program in a two-factor experimental design in random plots.

Investigated Characteristics

Plant height

Dry leaf weight (g), Fresh leaf weight (g), Leaf area, Membrane Permeability, Relative Water Content (RWC) were measured.

Fresh leaf weight

Leaf samples taken from the plant were kept in a tray with distilled water (covered with freshmen filter paper) for 24 hours and measured with a precision balance.

Leaf area

Leaf samples taken from the plant were measured with LICOR 3000 C leaf area measuring device.

Membrane Permeability

1 cm diameter discs were taken from the leaves of each plant brought to the laboratory after harvesting, the discs were washed with distilled water, 20 pieces were placed in glass bottles and 10 ml of distilled water was added to each of them. The prepared samples were left on the shaker for

24 hours and then the pure water in the bottles was poured into the tube and the EC1 value was measured on the EC meter. Then the water was returned to the bottles and autoclaved at 120 °C for 20 min and EC2 value was measured.

RMP (%) = (EC1 – EC0) / (EC2 – EC0) x 100 and the %EC value was found (Lutts et al., 1996)

Determination of relative water content

The largest and youngest leaves were collected from each pot. Leaves were immediately weighed to obtain fresh weight and dehydrated in a pool with double distilled water. The leaves were then rehydrated for 12 hours in a pool in an indoor environment at approximately 23 °C under light-free conditions. All leaves were placed in an oven at 70 °C for 72 hours. (Hossain et al 2010; Canavar et al., 2014).

RWC=[(Fresh Leaf Weight-Dry Leaf Weight) / (Rehydrated Leaf Weight-Dry Leaf Weight)] x 100

3. Results and Discussion

Analysis of variance was performed with the data obtained from the study and the results are shown in Table 1.

Table 1. ANOVA for the analyzed characteristics

CV	DF	Plant height	Dry Leaf weight	fresh Leaf weight	leaf area	ChIIa
S	2	27.754**	0.719**	13.58**	431.65**	0.784**
P.H	1	3.467ns	0.072ns	0.220ns	34.06ns	0.050ns
S * P.H	2	7.534ns	0.045ns	1.761*	90.36**	0.029ns

*, ** Significant p<0.05 and 0.01, D.F. Degree of freedom, respectively. S:Salinity, P.H.: potassium humate,

As seen in Table 1 and Table 2, the salt*potassium humate interaction was also significant for carotoneid, leaf area and fresh leaf weight. The effect of salt stress on all the traits examined was significant, as well as the effect of potassium humate for RMP and Carotoneid. Table 2 presents the mean values and groups of the analyzed traits. The mean values and groups of plant height of soybean plants at 4-leaf stage under different salt stress conditions and with and without potassium humate treatment are given in Table 2. According to the data obtained, it is seen that the plant height of soybean plants in the periods measured under 0.0 dS salt application conditions varied between 13.0 - 15.5 cm. The general average of plant height was 14.25 cm under non-salt conditions, 11.77 at 3.0 dS m^{-1} and 9.97 at 6.0 dS m^{-1}. According to these results, it was determined that plant height values were statistically significantly negatively affected as salt stress conditions increased. It becomes difficult for plants exposed to salt stress to take water from their roots. Saline soil creates an osmosis from the roots of the plants to the surrounding water. This causes plants to lose water and disrupts the water balance. Plants that cannot get enough water experience water stress and growth is reduced (Hailu and Mehari, 2021;Essa 2002; Tu 1981). According to the mean values of plant height, it is seen that potassium humate fertilizer applied under salt conditions of 3 and 6 dS m-1 increased plant height by 1 cm and 0.8 cm, respectively, compared to the control group (0 dS m^{-1}) plants, but this result was not found statistically significant. The study is in accordance with Kadam et al., 2011. Potassium humate applied under salt stress conditions positively affected plant growth characteristics.

Table 2. ANOVA for the analyzed characteristics

CV	DF	ChIIb (mg/g)	Karotoneid (mg/g)	RWC	RMP
S	2	0.101**	0.106**	158.103**	1776.776**
P.H	1	0.000ns	0.078**	0.135ns	286.889**
S * P.H	2	0.001ns	0.003*	2.194ns	0.025ns

*, ** Significant p<0.05 and 0.01, D.F. Degree of freedom, respectively. RWC:Relative water content, RMP: Relative membran permabilite

Plant dry leaf weight and the groups formed are given in Table 3. When we examine the mean values, it is seen that the plant dry leaf weight of soybean plants in the periods measured under 0.0 dS salt application conditions varied between 1.05 - 1.07 g. The average plant dry leaf weight was 1.062 g in control, 0.623 g in 3.0 dS conditions and 0.378 g in 6.0 dS conditions. These results show that dry leaf weight values are statistically significantly negatively affected as salt stress conditions increase. Under salt stress, plants begin to lose water due to high salt concentrations. The saline environment draws water from the roots of the plants towards the saline environment and the plants lose water. This leads to water loss in the leaves of the plants and consequently a decrease in dry leaf weight (Kadam et al., 2011). According to the average results, potassium humate fertilizer applied under salt conditions of 3 and 6 dS m^{-1} increases the dry leaf weight by 0.33 cm and 0.03 g, respectively, compared to plants not applied under the same conditions. In a study in maize, K+ contents in leaves and roots decreased by 34% and 61%, respectively, under salt stress (Jiang et al., 2017). In soybean, the positive and significant effect of potassium humate application on yield components under saline conditions has been found in previous studies (Abdelrasheed et al, 2021; Alharbi et al., 2022).

Table 3. Means for the characteristics examined (plant height and dry leaf weight)

	Plant Height (cm)			Dry Leaf weight (g)		
Salinity	Potassium Humate		Mean	Potassium Humate		Mean
	0	40 cc da^{-1}		0	40 cc da^{-1}	
0.0 dS m^{-1}	15.5	16.0	15.75 a	1.05	1.07	1.062 a
3.0 dS m^{-1}	12.2	13.2	11.77 b	0.46	0.79	0.623 b
6.0 dS m^{-1}	11.2	12.0	9.97 c	0.36	0.39	0.378 c
Mean	12.43	11.56		0.63	0.74	
LSD Salinity	1.563			0.161		
LSD Potassium	1.277			0.132		
LSD P*S	2.211			0.228		

Plant fresh leaf weight and the groups formed are given in Table 4. According to the results, it is seen that the fresh leaf weight of soybean plants varied between 4.65 - 5.41 g during the periods measured under control (0 dS m^{-1}) salt application conditions. After the start of salt application, it was between 2.81 - 4.17 dS m^{-1} at 3.0 dS m^{-1} and between 2.0 - 2.09 at 6.0 dS m^{-1}. The mean fresh leaf weight of the plant was 5.048 g under non-saline conditions, 3.49 g under 3.0 dS m^{-1} conditions and 2.04 g under 6.0 dS m^{-1} conditions. Salt stress can cause symptoms such as wilting and dropping of leaves in plants. This leads to a decrease in photosynthesis processes and negatively affects the nutrient synthesis of plants (Osman et al., 2017). In addition, it was determined that potassium applied to soybean grown under salt stress had statistically different effects at salt stress doses. Especially in salt stress environment such as 3.0 dS m^{-1}, it was determined that potassium application had a more positive effect than non-application, and there was a rapid decrease in the plant fresh weight of plants that were not applied potassium. Under 6.0 dS m^{-1} salt stress conditions, potassium application had no significant effect. In previous studies, it was found that fresh weight decreased similarly under salinity (Gouiaa et al., 2012 et al., 2012; Kurt et al., 2023). Leaf area averages and groups are given in Table 2. According to these results, it is seen that the leaf area of soybean plants in the periods measured under 0.0 dS salt application conditions varied between 19.42 - 24.14 cm². After the start of salt application, it was between 18.19 - 28.96 cm² at 3.0 dS m^{-1} and between 6.97 - 9.17 cm² at 6.0 dS m^{-1}. The mean leaf area was 21.873 cm² under no salt conditions, 23.580 cm² under 3.0 dS m^{-1} conditions and 8.073 cm² under 6.0 dS m^{-1} conditions. The data obtained from the results of this study (Gouiaa et al., 2012) are in agreement with the findings of the previous study. Potassium humate can reduce water loss caused by salt stress by regulating water balance in plants. High salt concentrations lead plants to lose water, but potassium humate can promote plants to take up more water from their roots. This helps regulate the water balance of plants and can increase the water content of leaves, expanding leaf area. The ability to maintain high chlorophyll content under saline conditions leads to high biomass, which is probably due to a greater leaf turgor resulting from a balanced osmotic potential, which in turn means higher photosynthesis and better growth (Gouiaa et al., 2012 et al., 2012). In a study in sunflower, chl content increased with NaCl (Heidari et al., 2014). These results are consistent with rice (Krishnamurathy et al., 1987) and soybean (Wang et al., 2001) and cotton (Higbie et al., 2010). Flowers et al., 1977 and Sohan et al., 1999 reported that salinity reduced leaf area index and increased leaf weight. In other words, the decrease in leaf area under salt stress is associated with an increase in leaf thickness. As a result, a decrease in leaf area occurs with salinity (Heidari et al., 2014).

Table 4. Means for the characteristics examined (fresh leaf weight and leaf area)

	Fresh Leaf Weight (g)			Leaf Area (cm^2)		
Salinity	Potassium Humate		Mean	Potassium Humate		Mean
	0	40 cc da^{-1}		0	40 cc da^{-1}	
0.0 dS m^{-1}	5.41 A a	4.65 B a	5.048 a	24.14	19.42	21.78 a
3.0 dS m^{-1}	2.81 B b	4.17 A b	3.49 b	18.19	18.96	18.56 a
6.0 dS m^{-1}	2.00 A b	2.09 B c	2.04 c	6.97	9.17	8.07 b
Mean	3.40	3.71		16.43	19.18	
LSD Salinity	0.804			4.265		
LSD Potassium	0.657			3.482		
LSD P*S	1.137			6.032		

ChIIa values and the groups formed are given in Table 5. According to the results, the plant ChIIa weight of soybean plants in the periods measured under 0.0 dS m^{-1} salt application conditions varied between 0.923 - 1.22 mg/g. After the start of salt application, it was between 0.660 - 0.789 mg/g at 3.0 dS m^{-1} and 0.37 mg/g at 6.0 dS m^{-1}. The average plant ChIIa weight was 1.092 mg/g under no salt conditions, 0.789 mg/g at 3.0 dS m^{-1} and 0.372 mg/g at 6.0 dS m^{-1} salt conditions. It is observed that ChIIa content decreased significantly with salt application. The positive effect of potassium humate was observed in average values under low salt conditions, but no potassium humate effect was observed under high salt conditions (6.0 dS m^{-1}). Munns (2002) reported that salinity causes plant cells to lose water and shrink and then cell elongation rates decrease. The change in cell elongation and cell division resulted in the formation of smaller sized leaves. Papp et al., 1983 and Beinsan et al., 2009 reported that an increase in leaf thickness under salinity can increase chl content. The increase in chl in leaves under salt stress may be due to an increase in the number of cloplasts (Misra et al., 1987). On the other hand, Zhao et al., 2007 and Yasar et al., 2008 revealed that chl content in oats decreased under increasing salinity conditions and this became more pronounced over time. ChIIb amounts and groups are given in Table 5. When the averages are examined, it is seen that the amount of ChIIb in soybean plants varied between 0.49-0.497 mg/g in the periods measured under 0.0 dS m^{-1} salt application conditions. After the start of salt application, it was determined to be between 0.35 - 0.386 mg/g at 3.0 dS m^{-1} and between 0.216 - 0.234 mg/g at 6.0 dS m^{-1}. The mean plant ChIIb weight was 0.497 mg/g under no salt, 0.368 mg/g at 3.0 dS m^{-1} and 0.226 mg/g at 6.0 dS m^{-1}. It is possible to say that salt stress has a negative and significant effect on chllb. Decrease in Chlorophyll concentration due to salinity has been previously recorded in rice plants (Ali et al., 2004; Tatatr et al., 2010). Lutts et al., 1996 and Zhao et al., 2010 reported that Chl a and Chl b were more significantly negatively affected. Kura-Hotta et al. 1987 suggested the decrease in Chl a/b as an indicator of plant senescence. According to the results obtained, potassium humate application did not affect the amount of chlb.

Table 5. Means for the characteristics examined (ChIIa and ChIIb)

	ChIIa (mg/g)			ChIIb (mg/g)		
Salinity	Potassium Humate		Mean	Potassium Humate		Mean
	0	40 cc da^{-1}		0	40 cc da^{-1}	
0.0 dS m^{-1}	0.923	1.22	1.092 a	0.497	0.490	0.497 a
3.0 dS m^{-1}	0.660	0.81	0.789 b	0.386	0.350	0.368 b
6.0 dS m^{-1}	0.37	0.37	0.372 c	0.234	0.216	0.226 c
Mean	0.65	0.8		0.497	0.490	0.497 a
LSD Salinity	0.134			0.064		
LSD Potassium	0.109			0.054		
LSD P*S	0.189			0.102		

Carotenoid contents and groups are given in Table 6. When we examined the results, it is seen that the plant carotenoid weight of soybean plants in the periods measured under 0.0 dS m^{-1} salt application conditions varied between 0.49-0.66 mg/g. After the start of salt application, it was determined to be between 0.36 - 0.350 mg/g at 3.0 dS m^{-1} and between 0.26 - 0.36 mg/g at 6.0 dS m^{-1}. The mean plant carotenoid weight was 0.576 mg/g at no salt, 0.445 mg/g at 3.0 dS m^{-1} and 0.311 mg/g at 6.0 dS m^{-1}. Salt stress caused a significant reduction in plant carotenoid content and this is in agreement with the results obtained in previous studies (Adhikari et al., 2020). The reduction in carotenoid and chlorophyll contents might be due to degradation of b-carotene and the negative effect of the accumulated salt ions (Ali et al., 2004; Gomes et al., 2011). It was observed that potassium humate application caused a significant increase in plant carotenoid content in both control and salt stress. Higher carotenoid and chlorophyll contents compared to potassium treatments were obtained by Hussein et al. (2014) in Jojoba plants. The increase in potassium ion and decrease in photosynthetic pigment and sodium ion under salt stress (Fayez and Bazaid, 2014) increased potassium content by potassium fertilizer.

Table 6. Means for the characteristics examined (Karotoneid and RWC)

	Karotoneid (mg/g)			RWC (Relative water content)		
Salinity	Potassium Humate		Mean	Potassium Humate		Mean
	0	40 cc da^{-1}		0	40 cc da^{-1}	
0.0 dS m^{-1}	0.49	0.66	0.576 a	94.528	93.014	93.771 a
3.0 dS m^{-1}	0.36	0.50	0.445 b	94.326	94.48	94.404 a
6.0 dS m^{-1}	0.26	0.36	0.311 c	84.795	85.63	85.214 b
Mean	0.37B	0.51A		91.22	91.04	
LSD Salinity	0.032			3.067		
LSD Potassium	0.028			2.504		
LSD P*S	0.046			4.338		

Plant RWC (relative water content) averages and groups are given in Table 7. According to the results, it is seen that the plant RWC of soybean plants varied between 93.014 - 94.528 mg/g in the periods measured under 0.0 dS m^{-1} salt application conditions. After the start of salt application, it was between 94.326 - 94.48 mg/g at 3.0 dS m^{-1} and between 84.795 - 85.63 mg/g at 6.0 dS m^{-1}. The mean plant RWC was 93.771 mg/g at no salinity, 94.404 mg/g at 3.0 dS m^{-1} and 85.214 mg/g at 6.0 dS m^{-1}. A negative and significant effect of salinity on RCW was found. RWC is an important parameter to understand the water balance of plants and to assess plant water stress. Plant water stress occurs when water uptake is reduced or water loss is increased. They found that RWC decreased in quinoa under saline conditions (El-Bassiouny and Bekheta 2005; Yan et al., 2020). A study in pea plants found that salt stress induced a decrease in RWC, with low (76.92%) RWC under salt stress (Khan et al., 2022). However, potassium humate had no significant effect on this trait. However, in a study, a significant positive effect of potassium humate on RWC under salinity was found (Alharbi et al., 2022).

Table 7. Means for the characteristics examined (RMP)

	RMP (Relative membran permabilite)		
Salinity	Potassium Humate		Mean
	0	40 cc da^{-1}	
0.0 dS m^{-1}	10.832	2.995	6.913 c
3.0 dS m^{-1}	35.607	27.523	31.565 b
6.0 dS m^{-1}	44.055	36.022	40.039 a
Mean	30.16	22.18	
LSD Salinity	6.512		
LSD Potassium	5.317		
LSD P*S	9.209		

Plant RMP (Relative membrane permability) averages and groupings are shown in Table 2. According to the results, the plant RMP weight of soybean plants in the periods measured under 0.0 dS m^{-1} salt application conditions varied between 2.995 - 10.832 mg/g. After the start of salt application, it was determined to be between 27.523 - 35.607 mg/g at 3.0 dS m^{-1} and between 36.022 - 44.055 mg/g at 6.0 dS m^{-1}. Plant RMP averaged 6.913 mg/g under saline-free conditions, 31.565 mg/g at 3.0 dS m^{-1} and 40.039 mg/g at 6.0 dS m^{-1}. The cell membrane acts as a selective barrier between the intracellular and extracellular environments and prevents the uncontrolled passage of substances inside the cell, and RMP is a measure used to assess this selective permeability of the cell membrane (Kwak et al., 2012). RMP increases when the cell membrane is damaged or under stress, which can cause the cell membrane to allow the passage of more substances than normal, indicating that the cell is negatively affected (Chung et al., 2021). Low RMP indicates that the cell membrane is intact and has normal permeability, while high relative membrane permeability may indicate that the cell membrane is damaged or under stress (Weldhois et al., 2021).

4. Conclusion

In this study to determine the tolerance ability of soybean against salinity, the plants were evaluated in terms of dry leaf weight, fresh leaf weight, plant height, Chl a, Chl b, relative water content (RWC), relative membrane permability (RMP), carotenoids after salinity under 0 dS m^{-1}, 3 dS m-1, 6 dS m^{-1} salinity conditions. As a result of the analysis, the content of photosynthetic pigments (chl a, chl b and carotenoids) decreased significantly when soybean plants were exposed to salinity conditions. However, changes in dry leaf weight, plant height, RWC traits were significantly affected by different salinity conditions. The positive effects of potassium humate application on ChIIa, ChIIb, fresh leaf weight, leaf area under salt stress conditions were observed more clearly than the effects on other traits. Relative membrane permability (RMP) was significantly and negatively affected by salinity. In terms of carotenoid properties, it was determined that the amount of carotenoid decreased while the degree of salinity increased. It was determined that salinity negatively affected the development of the plant. Especially in 3.0 dS m^{-1} and 6.0 dS m^{-1} salt stress conditions, soybean plant growth was negatively affected. As a result, foliar application of potassium humate fertilizer under high salinity conditions (6 dS m^{-1}) was found to stimulate plant growth under 3 dS m^{-1} salt conditions, while it did not affect plant growth factors under 6 dS m^{-1} conditions.

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

References

Abbasi, M.K., Tahir, M.M., Azam, W., Abbas, Z., Rahim, N.,2012. Soybean yield and chemical composition in response to phosphorus-potassium nutrition in Kashmir. *Agronomy Journal*, 104: 1476–1484.

Abdelrasheed, K.G., Mazrou, Y., Omara, A.E., Osman, H.S., Nehela, Y., Hafez, E.M., Rady, A.M.S., El-Moneim, D.A., Alowaiesh, B.F., Gowayed, S.M., 2021. Soil amendment using biochar and application of k-humate enhance the growth, productivity, and nutritional value of Onion (*Allium cepa* L.) under deficit irrigation conditions. *Plants*, 10: 2598.

Adhikari, B., Dhungana, S. K., Kim, I. D., Shin, D. H., 2020. Effect of foliar application of potassium fertilizers on soybean plants under salinity. *Journal of the Saudi Society of Agricultural Sciences*, 19(4): 261-269.

Alharbi, K., Rashwan, E., Hafez, E., Omara, A. E. D., Mohamed, H. H., Alshaal, T., 2022. Potassium humate and plant growth-promoting microbes jointly mitigate water deficit stress in soybean cultivated in salt-affected soil. *Plants*, 11(22): 3016.

Ali, Y., Aslam, A., Ashraf, M.Y., Tahir, G.R., 2004. Effect of salinity on chlorophyll concentration, leaf area, yield and yield components of rice genotypes grown under saline environment. *Environmental Science Journals* 1: 221-225

Aydin, A., Kurt, F., Hurkan, K., 2021. Key aromatic amino acid players in soybean (*Glycine max*) genome under drought and salt stresses. *Biocatalysis and Agricultural Biotechnology*, 35: 102094.

Aytaç, Z., Gülbandılar, A., Kürkçüoğlu, M., 2022. Humic Acid Improves Plant Yield, Antimicrobial Activity and Essential Oil Composition of Oregano (Origanum vulgare L. subsp. hirtum (Link.) Ietswaart). *Agronomy*, 12: 2086.

Beinsan, C., Camen, D., Sumalan, R., Babau, M., 2009. Study concerning salt stress effect on leaf area dynamics and chlorophyll content in four bean local landraces from Banat area. In *44th Croatian & 4th International Symposium on Agriculture,* Opatija, Bosnia and Herzegovina.

Bilashini, D.M., Thoithoi D.M., Jha, A.K., Anjoo, Y., Balusamy, A., Verma, V.K., Talang, H.D., Deshmukh, N.A., Rymbai, H., Assumi, S.R., 2018. Yield and Yield Attributes of Garden Pea (*Pisum sativum* var. *hortense* L.) as Influenced by Nutrient Management Practices under Agroclimatic Conditions of Meghalaya. *International Journal of Current Microbiology and Applied Sciences,* 7: 3447–3454.

Canavar, O., Gotz, K.P., Ellmer, F., Chmielewski, F. M., Kaynak, M. A., 2014. Determination of the relationship between water use efficiency, carbon isotope discrimination and proline in sunflower genotypes under drought stress. *Australian journal of crop science*, 8(2): 232-242.

Chugh, V., Vijaya Krishna, K., Pandit, A., 2021. Cell membrane-coated mimics: a methodological approach for fabrication, characterization for therapeutic applications, and challenges for clinical translation. *American Chemical Society Nano*, 15(11): 17080-17123.

Diao, M., Ma, L., Wang, J., Cui, J., Fu, A., Liu, H. Y., 2014. Selenium promotes the growth and photosynthesis of tomato seedlings under salt stress by enhancing chloroplast antioxidant defense system. *Journal of Plant Growth Regulation*, 33: 671-682.

El-Bassiouny, H. M., Bekheta, M. A., 2005. Effect of salt stress on relative water content, lipid peroxidation, polyamines, amino acids and ethylene of two wheat cultivars. *International Journal of Science and Research*, 7(3): 363-368.

El-Hashash, E.F., Abou El-Enin, M.M., Abd El-Mageed, T.A., Attia, M.A.E.-H., El-Saadony, M.T., El-Tarabily, K.A., Shaaban, A., 2022. Bread Wheat Productivity in Response to Humic Acid Supply and Supplementary Irrigation Mode in Three Northwestern Coastal Sites of *Egypt. Agronomy*, 12: 1499.

Essa, T. A., 2002. Effect of salinity on growth and nutrient composition of three soybean (Glycine max L. Merrill) cultivars. *Journal of Agronomy and Crop Science*, 188(2): 86-93.

Fayez, K. A., Bazaid, S. A., 2014. Improving drought and salinity tolerance in barley by application of salicylic acid and potassium nitrate. *Journal of the Saudi Society of Agricultural Sciences*, 13(1): 45-55.

Flowers, T.J., Torke, P.F., Yeo, A.R., 1977. The mechanism of salt tolerance in halophytes.Ann. Rev. *Plant Physiology,* 28:89-121.

Gomes, M. A. D. C., Suzuki, M. S., Cunha, M. D., Tullii, C. F., 2011. Effect of salt stress on nutrient concentration, photosynthetic pigments, proline and foliar morphology of Salvinia auriculata Aubl. *Acta Limnologica Brasiliensia*, 23: 164-176.

Gouiaa, S., Khoudi, H., Leidi, E. O., Pardo, J. M., Masmoudi, K., 2012. Expression of wheat Na+/H+ antiporter TNHXS1 and H+-pyrophosphatase TVP1 genes in tobacco from a bicistronic transcriptional unit improves salt tolerance. *Plant Molecular Biology*, 79: 137-155.

Hafez, E.M., Omara, A.E.D., Alhumaydhi, F.A., El-Esawi, M.A., 2021. Minimizing hazard impacts of soil salinity and water stress on wheat plants by soil application of vermicompost and biochar. *Physiologia Plantarum*, 172: 587–602.

Hailu, B., Mehari, H., 2021. Impacts of soil salinity/sodicity on soil-water relations and plant growth in dry land areas: A review. *Journal of Natural Science*, 12: 1-10.

Heidari, A., Bandehagh, A., Toorchi, M., 2014. Effects of NaCl stress on chlorophyll content and chlorophyll fluorescence in sunflower (Helianthus annuus L.) lines. *Yuzuncu Yıl University Journal of Agricultural Sciences*, 24(2): 111-120.

Higbie, S.M., Wang, F., Stewart, J.M., Sterling, T.M., Lindemann, W.C., Hughs, E., Zhang, J. 2010. Physiological response to salt (NaCl) stress in selected cultivated tetraploid cottons. *International Journal of Agronomy*. 10:1155-1167

Hussein, M. M., Mehanna, H., Zaki, S., Hay, N. F. A., 2014. Influences of salt stress and foliar fertilizers on growth, chlorophyll and carotenoids of jojoba plants. *Middle East Journal of Agriculture Research*, 3: 221-226.

Hossain, M.I., Khatun, A., Talukder, M.S.A., Dewan, M.M.R., Uddin, M.S., 2010. Effect of drought o physiology and yield contributing characters of sunflower. *Bangladesh Journal of Agricultural Research*, 35: 113-124.

Jiang, C., Zu, C., Lu, D., Zheng, Q., Shen, J., Wang, H., Li, D., 2017. Effect of exogenous selenium supply on photosynthesis, Na+ accumulation and antioxidative capacity of maize (*Zea mays* L.) under salinity. *Scientific Reports*, 7(1): 42039.

Kadam, A. S., Wadje, S. S., Patil, R., 2011. Role of potassium humate on growth and yield of soybean and black gram. *International Journal of Pharmacy and Biological Science*, 1: 243-246.

Khan, M. A. H., Baset, Mia, M. A., Quddus, M. A., Sarker, K. K., Rahman, M., Skalicky, M., Hossain, A., 2022. Salinity-induced physiological changes in pea (*Pisum sativum* L.): Germination rate, biomass accumulation, relative water content, seedling vigor and salt tolerance index. *Plants*, 11(24): 3493.

Krishnamurathy, R., Anbazhagan, M., Bhagwat, K.B., 1987. Effect of sodium chloride toxicity on chlorophyll break down in rice. *Indian Journal of Agricultural Science*. 57: 567-570.

Kwak, Y. K., Vikström, E., Magnusson, K. E., Vécsey-Semjén, B., Colque-Navarro, P., Möllby, R., 2012. The Staphylococcus aureus alpha-toxin perturbs the barrier function in Caco-2 epithelial cell monolayers by altering junctional integrity. *Infection and Immunity*, 80(5): 1670-1680.

Kwiatowsky, J., 1998. Salinity classification, mapping and management in Alberta. *Food and Rual Development and Agriculture and Agrifood*. Canada.

Kura-Hotta, M., Satoh, K., Katoh, S., 1987. Relationship between photosynthesis and chlorophyll content during leaf senescence of rice seedlings. *Plant Cell Physiology*, 7: 1321-1329

Kurt, C. H., Tunçtürk, M., Tunçtürk, R., 2023. Tuzluluk stresi koşullarında yetiştirilen soya (*Glycine max* L.) bitkisinde bazı fizyolojik ve biyokimyasal değişimler üzerine salisilik asit uygulamalarının etkileri. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, 60.1: 91-101.

Lutts S, Kinet, J.M, Bouharmont J. 1996. NaCl Induced senesence in leaves of rice (*Oryza sativa* L.) cultivars differing in salinity resistance. *Annals of Botany* 78: 389-398.

Misra, A.N., Sahl, S.M., Misra, M., Singh, P., Meera, T., Das, N., Har, M., Sahu, P., 1997. Sodium chloride induced changes in leaf growth, and pigment and protein contents in two rice cultivars. *Biology of Plant*, 39:257-262.

Munns, R., 2002. Comparative physiology of salt and water stress. *Plant Cell Environment*, 25:239-250

Munns, R., Tester, M., 2008. Mechanisms of salinity tolerance. Ann. Rev. *Plant Biol*ogy, 59: 651–681.

Nelson, K.A., Motavalli, P.P., Stevens, W.E., Kendig, J.A., Dunn, D., Nathan, M., 2012. Foliar potassium fertilizer additives affect soybean response and weed control with glyphosate. *International Journal of Agronomy*, 461894.

Nusrat, N., Shahbaz, M., Perveen, S., 2014. Modulation in Growth, Photosynthetic Efficiency, Activity of Antioxidants and Mineral Ions by Foliar Application of Glycinebetaine on Pea (*Pisum sativum* L.) under Salt Stress *Acta Physiologiae Plantarum*, 36: 2985–2998.

Okba, S.K., Mazrou, Y., Elmenofy, H.M., Ezzat, A., Salama, A. M., 2021. New Insights of Potassium Sources Impacts as Foliar Application on 'Canino' Apricot Fruit Yield, Fruit Anatomy, Quality and Storability. *Plants*, 10: 1163.

Osman, M. E., Mohsen, A. A., Elfeky, S. S., Mohamed, W., 2017. Response of salt-stressed wheat (Triticum aestivum L.) to potassium humate treatment and potassium silicate foliar application. *Egyptian Journal of Botany*, *57*(7th International Conf.), 85-102.

Papp, J.C., Ball, M.C., Terry, N., 1983. A comparative of the effects of NaCl salinity on respiration, photosynthesis and leaf extention in Beta vulgaris L. (Sugar beet). *Plant Cell Envir.* 6:675-677.

Rozema, J., Flowers, T., 2008. Crops for a salinized world. *Science*, 322(5907): 1478-1480.

Sharma, J.R., 2006. *Statistical & Biometrical Techniques in Plant Breeding*; New Age International: New Delhi, India, 432p.

Sohan, D., Jasoni, R., Zajicek, J., 1999. Plant-water relation of NaCl and calcium treated sunflowers plants. *Environmental Experimental Botany*. 42:105-111.

Tatar, Ö., Brueck, H., Gevrek, M. N., Asch, F., 2010. Physiological responses of two Turkish rice (Oryza sativa L.) varieties to salinity. *Turkish Journal of Agriculture and Forestry*, 34(6): 451-459.

Tu, J.C., 1981. Effect of salinity on Rhizobium-root-hair interaction, nodulation and growth of soybean. *Canadian Journal of Plant Science*, 61(2): 231-239.

Turan, M., Ekinci, M., Kul, R., Kocaman, A., Argin, S., Zhirkova, A.M., Perminova, I.V., Yildirim, E., 2022. Foliar Applications of Humic Substances Together with Fe/Nano Fe to Increase the Iron Content and Growth Parameters of Spinach (Spinacia oleracea L.). *Agronomy*, 12: 2044.

Ullah, M.A., Aamir, S.S., Haider, H., Adil, B., Mahmood, I.A., Badar-uz-Zaman, H. S., 2018. Effect of salinity, humic acid, biozote and vermicompost on soil physicochemical properties and olive plants species. *Journal of Agricultural Science and Practice*, 3*:* 27-32.

Wang, D., Shannon, M.C., Grieve, C. M., 2001. Salinity reduces radiation absorption and use efficiency in soybean. *Field Crops Research,* 69: 267-277

Veldhuis, M. J., Kraay, G. W., Timmermans, K. R. 2001. Cell death in phytoplankton: correlation between changes in membrane permeability, photosynthetic activity, pigmentation and growth. *European Journal of Phycology*, 36(2): 167-177.

Yan, H. O. N. G., Shah, S. S., Zhao, W., Liu, F.U.L.A. I. 2020. Variations in water relations, stomatal characteristics, and plant growth between quinoa and pea under salt-stress conditions. *Pakistan Journal of Botany*, 52(1): 1-7.

Yasar, F., Ellialtioglu, S., Yildiz, K., 2008. Effect of salt stress on antioxidant defense systems, lipid peroxidation, and chlorophyll content in green bean. *Russian Journal of Plant Physiology*, 55: 782-786.

Zhao, G.Q., Ma, B.L., Ren, C.Z. 2007. Growth, gas exchange, chlorophyll fluorescence, and ion content of naked oat in response to salinity. *Crop Science,* 47:123-131.

Zhu, J. K., 2003. Regulation of ion homeostasis under salt stress. *Current Opinion in Plant Biology*, 6: 441–445.

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