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EFFECT OF SALINITY ON GRAFTED EGGPLANT SEEDLINGS

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USED ABBREVIATIONS

D.W.	Dry weight
F.W.	Fresh weight
NaCl	Sodium chloride
ROS	Reactive oxygen species
RWC	Relative water content
SPAD	Soil Plant Analysis Development
T.W.	Turgid weight

1. INTRODUCTION

Common eggplant (*Solanum melongena* L.), also known as aubergine, brinjal eggplant, or eggplant, is a tropical and subtropical warm-season crop that belongs to the Solanaceae family (Ribeiro et al. 1998). According to the FAO Statistical Database for 2021, China is the world's largest producer, with nearly 37,5 million tons produced, followed by India with approximately 13 million tons. Chinese and Arabs have a long history of cultivating and consuming eggplant daily (Antonini et al. 2002). In the Mediterranean basin, another important area for eggplant production, Egypt is the largest producer, with nearly 1,3 million tons, followed by Turkey. The eggplant production in Hungary in 2021 was around 1000 tonnes with a harvested area of 50 ha (FAO 2021).

The most common variety of aubergine produced and consumed in Europe and South America is the one that has a fruit with dark purple skin, it is long (12 cm to 25 cm) and not so wide (6 to 9 cm) (FAO 2021, Ribeiro et al. 1998), and scarlet (*Solanum aethiopicum* L.) and gboma (*Solanum macrocarpon* L.) are two other cultivated eggplant species with local importance in Africa (Daunay and Hazra 2012).

The purple color of the eggplant's skin is mostly due to anthocyanins, which have been shown in some studies to impact cognitive and motor performance, as well as brain function (Morris and Taylor 2017). The fruit contains a lot of water and plenty of calcium, phosphorus, potassium, fiber, folic acid, sodium, and vitamins B and C (Alhaithloul 2019, Derivi et al. 2002). *Solanum melongena* L. is one of the most important species of the Solanaceae family in current cultivated areas, is attributed to the fact that its fruit is a good source of vitamins and mineral salts, antioxidants, and medicinal properties due to the concentration of flavonoids, phenolic compounds which provide the ability to lower plasma cholesterol and hypoglycemic effect (Ribeiro et al 1998; Jorge et al. 1998, Derivi et al. 2002). The major limitations to its cultivation are the low availability of water and nutrients in the soil during its life cycle. Its response to abiotic factors such as salinity and water stress has, is now receiving the needed attention (de Oliveira et al. 2009).

Salinity stress occurs when soil or irrigation water contains high levels of salts, which can adversely affect plant growth, development, and yield. Salinity stress is a major challenge facing agricultural production worldwide, particularly in arid and semi-arid regions where water resources are limited. In eggplant cultivation, salinity stress can cause a range of physiological, biochemical, and molecular changes that impact plant growth and productivity. The effects of salinity stress on eggplant plants have been studied in recent years, with research focusing on understanding the mechanisms the plant uses to respond to and tolerate salinity stress (Ahanger and Agarwal 2017, Fatma et al 2014, Khan et al. 2014).

Plant breeding has primarily aimed to increase yield, confer disease resistance, make plants more resistant to mechanical damage, and improve overall postharvest performance. However, the process has been slow and inefficient thus far due to a lack of viable selection methods, such as genetic markers. Grafting is regarded as a quick alternative to a rather slow breeding technique for improving vegetable crop environmental stress tolerance (Mozafarian and Kappel 2020).

Grafting is a horticultural technique that involves joining the rootstock of one plant to the scion of another, resulting in a new plant with improved and desired traits (Colla, Pérez-Alfocea, and Schwarz 2017, Lee and Oda 2010). Eggplant grafting can improve plant vigor and overall plant health. This increased vigor can also result in earlier fruit production and a longer harvest season (Moncada et al. 2013, Sabatino et al. 2019, 2020, Mozafarian and Kappel 2020). Grafted plants have been shown to have larger and more robust root systems, which allow them to better withstand stress and environmental fluctuations (Savvas et al. 2010, Lee and Oda 2010, Lee et al. 2010)

Eggplant grafting offers numerous advantages to growers, including disease resistance, increased yield, and improved plant vigor. As such, it has become an increasingly popular technique in the eggplant industry, with many growers adopting it as a standard practice.

The purpose of this study is to assess the effect of salinity on the morphophysiological and ion content of grafted and non-grafted eggplant seedlings.

2. LITERATURE REVIEW

2.1. Botanical features

The eggplant is semi-woody and has erect stems that grow to a height of 1.0 to 1.8 m. The plant appears to be a very compact bush due to the intense formation of lateral branches. The root system can extend to depths of more than 1.0 m. The leaves are simple and hairy, with an oval or oblong leaf blade. It may have thorns depending on the cultivar (Ribeiro et al. 1998).

Flowers can vary from 3 to 5 cm in diameter and are either solitary or distributed in summit-type inflorescences. Spines are frequently found on the calyx, which has 5 to 7 sepals. The corolla has 5 to 6 lilac to violet petals and is gamopetalous. The 5–6 stamens are free, erect, yellow, and have especially short filaments (Ribeiro et al. 1998, Daunay et al. 2001a). *Solanum melongena* L. reproduces mainly through self-fertilization. Natural cross-pollination varies by cultivar and other environmental factors, with an estimated average of 6 to 7%, though it can reach 70% (Daunay 2008). Cross-pollination increases in areas where pollinating insect populations exist.

The fruits are large, berry-like, and come in a variety of shapes (oval, oblong, round, oblong-elongated, elongated, and so on), and are usually shiny, white, pink, zebrin, yellow, purple, or black. The fruit is high in minerals and vitamins, and its nutritional value is comparable to that of the tomato (Ribeiro et al. 1998, Nothmann 1986, Sękara et al. 2007).

Originally from tropical and subtropical climates, it grows best on hot climates with an average temperature of 25°C, a relative humidity of 80% and a photoperiod of 10-12h (Sękara et al. 2007). It can be grown all year under these conditions (Ribeiro et al. 1998). Planting can be done in greenhouses or in spring-summer in regions where average winter temperatures are less than 18 °C (Ribeiro et al. 1998). Temperatures below 14 °C inhibit growth, flowering, and fruiting (Ribeiro et al. 1998, Nothmann and Koller 1975). High temperatures (32°C) on the other hand, can affect the plant by accelerating the maturation of fruits that are not yet fully developed, and temperatures above 35°C for extended periods make pollen unviable, compromising pollination and resulting in defective fruits or non-development from them (Ribeiro et al. 1998).

Eggplant grows best in sandy-clay soils that are deep and well-drained. Good soil preparation, such as acidity correction and fertilizer application, is required for high productivity (Nothmann 1986).

2.2. Salinity stress

Soil salinity is a major issue impacting agricultural regions all over the world. It refers to the accumulation of salt in the soil, which results in decreased soil fertility, lower crop output, and, in certain situations, crop failure. Salinity can occur naturally in desert locations with high evaporation rates, but human activities such as irrigation and fertilizer use can exacerbate the situation (Machado and Serralheiro 2017, Soda et al. 2016).

According to the Food and Agriculture Organization (FAO), about 20% of the world's cultivated land is affected by soil salinity, with some regions suffering more than others. For example, in the Middle East and North Africa, nearly 30% of agricultural lands are affected by salinity, while in South Asia, it is about 8%.

Salinity stress occurs when soil or irrigation water contains high levels of salts, which can adversely affect plant growth, development, and yield. Salinity stress is a major challenge facing agricultural production worldwide, particularly in arid and semi-arid regions where water resources are limited (Khataar et al. 2018, Machado and Serralheiro 2017). The main constraints to plant cultivation are the limited availability of water, nutrients, and salt concentration in the soil throughout the plant's life cycle (de Oliveira et al. 2009).

Physiological responses to salinity stress in plants include reduced growth rates, decreased leaf area, and increased water loss through transpiration (Assaha et al 2013, Ghanem et al. 2010). Salinity stress can also cause oxidative stress in plants, leading to the accumulation of reactive oxygen species (ROS) and the disruption of cellular membranes (Assaha et al 2013, Ghanem et al. 2010). Furthermore, salinity stress can disrupt nutrient uptake and transport in plants, resulting in imbalances in mineral nutrition and ion toxicity (Al-Taey and Majid 2018).

2.3. Salinity stress on eggplant

Salinity stress produces osmotic stress, ion toxicity, and nutritional imbalance in plants, which results in physiological and morphological alterations. This kind of environmental condition can impact the growth, development, and fruit quality of eggplants (Ahanger and Agarwal 2017, Khan et al. 2014, Iqbal et al. 2015).

Albacete et al. (2015), for example, investigated the effects of salt stress on grafted eggplant and it was observed that it reduces plant growth, yield, and fruit quality, and the degree of the effect varied according to the rootstock utilized. Assaha et al. (2013) and Ghanem et al. (2010) also investigated the effects of salinity stress on eggplant, and they found that salty conditions do not just affect the growth rates and yield, but additionally, decreased stem diameter, and root length, decreased leaf area, and increased water loss through transpiration, and it can cause oxidative stress in plants, leading to the accumulation of reactive oxygen species (ROS) and the disruption of cellular membranes.

Plant physiology and biochemistry are affected by stress. Ion buildups, such as Na^+ and Cl^-, are found in plant tissues generating oxidative stress, which damages membranes and macromolecules (Munns and Tester, 2008). Furthermore, salinity stress can result in nutritional imbalances, impacting the uptake and use of important elements such as N, P, K, and Ca (Munns and Tester 2008, Al-Taey and Majid 2018).

Biochemical responses of eggplant plants to salinity stress include the accumulation of compatible solutes, such as proline and glycine betaine, which help regulate the osmotic balance and protect cellular membranes from oxidative damage (Abbas et al. 2010). Salinity stress can also induce changes in the expression and activity of various enzymes involved in plant metabolism, including antioxidant enzymes, stress-responsive enzymes, and ion transporters as described by Al-Taey and Majid (2018). Molecular responses of eggplant plants to salinity stress involve changes in gene expression patterns, particularly stress-responsive genes and signaling pathways (Ghanem et al. 2010).

2.4. Grafting

2.4.1. Introduction

Grafting of vegetable crops is used to provide resistance to soil pests and pathogens, increase tolerance to abiotic stresses, improve water or nutrient uptake, or increase scion vigour (King et al. 2008; Lee and Oda 2010). It is a technique where two plants are joined together to form a single plant (Savvas et al 2010). The upper part of the plant, called the scion, is chosen for its desirable characteristics such as high yield or resistance to disease, while the lower part, called the rootstock, is chosen for its strong root system or tolerance to environmental stressors. Grafting is commonly used in vegetable production, especially in high-value crops such as tomatoes, eggplants, peppers, and the Cucurbitaceae family like cucumber, melon, and watermelon, with the aim to enhance production and resource efficiency (Gaion et al. 2018, Kyriacou et al. 2017, Schwarz et al. 2010)

Advantages of vegetable grafting:

1. Disease resistance: One of the most significant advantages of grafting is the ability to create disease-resistant plants. Many diseases that attack the roots or stems of plants can be controlled by grafting onto a resistant rootstock. For example, tomatoes grafted onto a resistant rootstock have been shown to be resistant to soil-borne diseases (Bie et al. 2017, Lee et al. 2010, Chung and Lee 2007).

2. Increased yield: Grafted plants can produce higher yields compared to non-grafted plants, due to the stronger root system provided by the rootstock. This results in better water and nutrient uptake, leading to improved plant growth and productivity (Bie et al. 2017, Lee et al. 2010, Chung and Lee 2007, Dias et al. 2016).

3. Tolerance to environmental stressors: Grafted plants have been shown to have increased tolerance to environmental stressors such as drought, high temperatures, and soil salinity. This is due to the rootstock's ability to absorb water and nutrients more efficiently, and to maintain root growth under adverse conditions (Bie et al. 2017, Mozafarian and Kappel 2020, Dias et al. 2016).

Disadvantages of vegetable grafting:

1. Cost: Grafting can be an expensive process, especially when compared to traditional seed propagation. The cost of rootstocks and the additional labor required for grafting can make it difficult for small-scale farmers to adopt this technique (Bie et al. 2017)

2. Technical expertise: Grafting requires technical expertise and skills that may not be readily available to farmers. It is also a time-consuming process that requires specific tools and materials (Bie et al. 2017, Kumar and Kumar 2017).

3. Compatibility issues: The success of grafting depends on the compatibility between the scion and the rootstock. If the two plants are not closely related, the graft may fail, resulting in a loss of time and resources (Bie et al. 2017, Colla et al. 2017, Lee 1994).

2.4.2. Effect of grafting on eggplant growth and yield

Several researches have been conducted to explore the impact of grafting on eggplant production. For example, using wild eggplant (*Solanum sisymbriifolium*) as a scion increases tomato and eggplant yield (Bletsos and Olympios 2008, Bletsos et al. 2003, Arvanitoyannis et al 2005). Grafted plants showed increased fruit yield, total yield, and fruit weight, according to the studies. It was also discovered that grafted plants were more resistant to soil-borne diseases such as *verticillium* wilt (Ioannou 2001).

Gisbert et al. (2011) investigated the impact of several rootstocks on eggplant growth and yield. Certain rootstocks, such as *Solanum torvum* and *Solanum aethiopicum*, boosted fruit output and quality when compared to non-grafted plants, according to the researchers.

Grafting can effectively increase eggplant yield and quality, particularly in environments where disease, pest, or abiotic stressors are present (Bletsos and Olympios 2008, Bletsos et al. 2003, Arvanitoyannis et al 2005).

2.4.3. Effect of grafting on salinity

The higher salt tolerance of grafted plants has frequently been linked to their root systems. When it comes to soil-related stresses like salt, the root systems are the most important organs of plants since they are primarily responsible for reducing the adverse impacts of salt stress on shoot growth (Kumar and Kumar 2017).

The root system is crucial in grafted plants' response to saline stress (Colla et al. 2010). Root length, density, and length, and hence surface area, could all have a role in ion and water uptake (Koevoets et al. 2016).

Salinity is a significant abiotic stressor that can have a negative impact on plant growth and productivity (Rouphael et al. 2018). According to Zhen et al. (2011) and Liu et al. (2013), under salinity stress, grafted plants showed more biomass accumulation and improved water usage efficiency than non-grafted plants. They also discovered that grafted plants had higher chlorophyll content and photosynthetic rates than non-grafted plants, meaning that they performed better physiologically.

Ion imbalance, ion toxicity, and hyperosmotic stress occur in plants exposed to excessive salt concentrations. These fundamental consequences typically result in secondary stresses, such as oxidative damage (Zhu 2001). In response to salt stress, grafted plants generate a variety of physiological and biochemical reactions. Some of them are the salt exclusion in the shoot and salt ion accumulation in the root, the salt ion segregation in the vacuole, the antioxidant protection, and the induction of hormone-mediated changes in plant growth (Pessarakli 2020). Under stress caused by NaCl, grafted eggplant demonstrated reduced leaf Na^{+} and Cl^{-} concentrations compared to self-rooted plants (Bai et al. 2005, Wei et al. 2007).

3. MATERIAL AND METHODS

The experiment was conducted at the Department of Vegetable and Mushroom Growing, at the Institute of Horticultural Science of the Hungarian University of Agriculture and Life Science in 2022.

3.1. Plant material and Seedling production

'Madonna' eggplant (Monsanto, USA) features a vigorous plant with a well-developed root system. It bears medium-sized, black-colored fruit with white flesh and a few seeds. It is ideal for greenhouse growth. In this study, 'Madonna' (*Solanum melongena* L.) was utilized as a scion, and three rootstocks were tested: Taibyou, Hikyaku, and a non-grafted 'Madonna' eggplant as a control.

Hikyaku: (*Solanum melongena* × *Solanum integrifolium*), Kaneko (Japan), intermediate resistance to *Verticillium* wilt and *Fusarium* wilt.

Taibyou: (*Solanum grandifolium* × *Solanum melongena*), Takii Seeds (Japan), resistant to *Verticillium* wilt and *Fusarium* wilt.

The rootstock seeds (Taibyou and Hikyaku) were sown ten days earlier than ‘Madonna’ scion. Two seeds were placed per pot (7 cm × 7 cm × 6.2 cm) in groups of 32 in each tray to produce grafted and non-grafted seedlings. The seeds were sown on a peat mixture. Then they were placed in 18 hours of light, 25-26 °C temperature, and 70 to 80% of air humidity. Irrigation with regular water is essential to maintain the substrate moist until seed germination. The seedlings received irrigation using Ferticare starter (15: 30: 15), EC 1.8-2 dS.m^{-1} (Mozafarian 2023).

When the seedlings were sufficiently grown, the 'Madonna' eggplant scion was grafted onto Taibyou and Hikyaku. The splice grafting method was used to graft seedlings by hand (Figure 1). The cutting was done with a normal cutting blade that had been sanitized with 70% ethanol. The grafting technique utilized was completed by adding a silicone clip at the graft union to ensure proper fit and pressure was applied. The grafted plants were kept for one week to heal under low light and high humidity conditions before being returned to normal conditions (Lee et al. 2010, Mozafarian 2023).

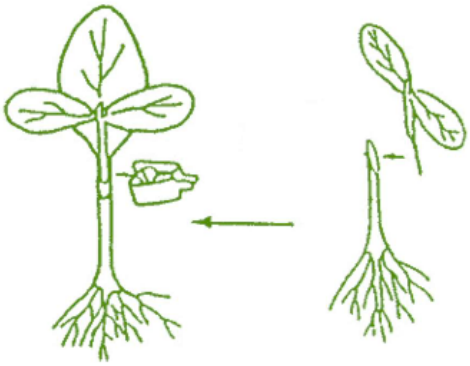

Figure 1. Splice grafting method used (Lee et al. 2010)

Figure 2. Growing chamber at the laboratory of the Department of Vegetables and Mushroom growing

Figure 3. Grafted seedling after one week

3.2. Growing conditions, irrigation, treatment applications, and measurements

A total of 2 types of nutrient solutions were used: Ferticare I (14:11:25 + microelements) with an EC value of 3.80 $dS.m^{-1}$ for control plants, Ferticare I + 40 mM NaCl with an EC value of 11.40 $dS.m^{-1}$ for salt stress condition. The experiment was conducted with four replications.

3.2.1. Evaluation method

Three weeks after the salt treatment application, some morphophysiological traits were evaluated. Leaf number was counted after the development of the first 2 true leaves. The Soil Plant Analysis Development, SPAD-502 Chlorophyll Meter (Minolta Camera Co., Ltd., Japan) was used to determine the relative chlorophyll content.

The stem and rootstock diameter (mm) were measured with a digital caliper. For the root length (cm) was used a ruler, as well as for stem height (cm).

Microscopic images of the roots were used to count root hair numbers by using the software ImageJ (Version 1.8.0_172; Research Services Branch, National Institute of Mental Health, Bethesda, MD, USA).

The seedlings were taken out from their containers of growth. Running water washed away the root-clinging substrate. The aerial portion was then separated from the root section. To drain excess water from the root surface, tissue was used. Root diameters (mm) were measured with a digital caliper, and root lengths were measured with a ruler (cm).

Following that, each root was placed on a digital scale and its weight was recorded (g). The samples were then placed in a 60°C oven for 12 hours. The dried root was taken out of the oven and set aside to cool. The weight of the root (g) was measured using a digital scale (Mozafarian 2023).

Individual leaves were detached from the stem and weighed (g) to determine their fresh weight (F.W.), in order to determine relative water content (RWC). Leaves were floated in distilled water inside a closed petri dish to quantify the turgid weight (T.W.) (g). After 12 hours, leaf samples were weighed (Kaya et al. 2002). Following the imbibition phase, leaf samples were dried in an 80°C prepared oven for 48 hours before being measured by dry weight (D.W.) with a digital scale (g) (Mozafarian 2023). The following formula was used to determine RWC (%) (Pieczynski et al. 2012): RWC (%) = [(F.W-D.W.)/(T.W.-D.W.)] × 100.

On homogeneous samples, the Na^+ and K^+ concentrations (mg/g dw) on leaves, stems, and roots were measured using an ICP-OES spectrometer (IRIS Thermo Jarrel ASH, Corp., Franklin, MA, USA) (Bőhm et al. 2017).

3.3. Statistical analysis

The data was analyzed using Statistix 8 software (Tallahassee, FL, USA). The salinity research was carried out as a factorial experiment using a completely randomized design (CRD) with two factors including two different rootstocks and salinity level. Data were subjected to the two-way analysis of variance (ANOVA), and means were separated using the LSD comparison test at $p<0.05$.

4. RESULTS AND DISCUSSION

The properties of the rootstock's root system frequently impact the performance of grafted plants under stressful situations. Root length (cm) and density, root hairs, and root surface area all play important roles in regulating salt tolerance in grafted plants (Colla et al. 2010, He et al. 2009). A healthy root system can increase plant growth and crop productivity by producing more cytokinin and transporting water to the shoot system via xylem sap (Oztekin and Tuzel 2011).

Analysis of variance showed that fresh and dry weight (g) of the root was not influenced by salinity and different rootstocks (Table 1), Mozafarian (2023) observed an increase in these measurements when grafted into Hikyaku rootstock. The results revealed that salinity significantly decreased the hair number in non-grafted seedlings as compared to non-stress conditions (Table 1, Figure 4).

Table 1. Effect of salinity on grafted and non-grafted seedling root

Treatment	Rootstock	Fresh weight (g)	Dry weight (g)	Hair number	Length (cm)
Interaction effect of salinity and rootstock on root					
Control	Non-grafted	3.02 ab	0.27 a	48.83 a	21.50 a
	Taibyou	3.12 a	0.24 ab	49.54 a	12.50 bc
	Hikyaku	1.52 b	0.10 c	51.66 a	21.75 a
Salinity	Non-grafted	3.12 a	0.29 a	35.43 b	16.75 bc
	Taibyou	2.59 ab	0.12 bc	48.70 a	14.50 c
	Hikyaku	2.68 ab	0.22 abc	51.33 a	19.50 ab
Main effect of salinity and rootstock on root					
Control		2.80 a	0.21 a	50.00 a	19.91 a
Salinity		2.68 a	0.20 a	45.15 b	16.91 b
	Non-grafted	3.07 a	0.28 a	42.13 b	19.12 a
	Taibyou	3.05 a	0.18 ab	49.12 a	15.50 b
	Hikyaku	2.10 a	0.16 a	51.50 a	20.62 a
Salinity		ns	ns	*	*
Rootstock		ns	ns	*	*
Salinity × Rootstock		ns	ns	*	ns
CV		38.46	44.57	28.43	13.15

‡Different letters within the same column are significantly different between means of replications (4 plants in each replication) according to LSD test at $P<0.05$. ‡‡ ns= not significant, * = significant at $P<0.05$, ** =significant at $P<0.001$, ***= significant at $P<0.0001$ ‡‡‡ Non-grafted = *Solanum melongena* L.; Taibyou = *Solanum grandifolium* × *Solanum melongena;* Hikyaku = *Solanum melongena* × *Solanum integrifolium*

A previous study showed that root dry mass was reduced in tomatoes grown under saline stress, however, the drop was less in plants grafted on rootstocks compared to nonsaline conditions (He et al. 2009). In this study, it is visible that the root volume and length (cm) were bigger on the seedlings grafted onto the Hikyaku rootstock (Figure 5).

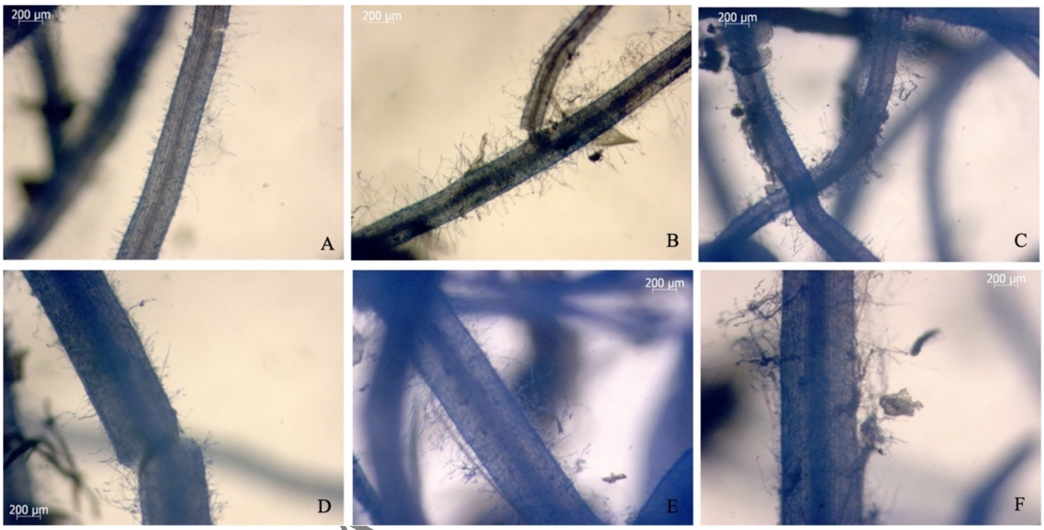

Figure 4. Root hair observation of grafted and non-grafted rootstocks.

‡ A) Non-grafted 'Madonna' (*Solanum melongena* L.) root irrigated with fertilizer solution; B) Taibyou (*Solanum grandifolium* × *Solanum melongena*) rootstock irrigated with fertilizer solution; C) Hikyaku (*Solanum melongena* × *Solanum integrifolium*) rootstock irrigated with fertilizer solution; D) Non-grafted 'Madonna' (*Solanum melongena* L.) root irrigated with saline solution; E) Taibyou (*Solanum grandifolium* × *Solanum melongena*) rootstock irrigated with saline solution; F) Hikyaku (*Solanum melongena* × *Solanum integrifolium*) rootstock irrigated with saline solution.

Figure 5. Root structure in grafted and non-grafted eggplant seedling on different rootstocks.

‡ A) Non-grafted 'Madonna' (*Solanum melongena* L.) root irrigated with fertilizer solution; B) Taibyou (*Solanum grandifolium* × *Solanum melongena*) rootstock irrigated with fertilizer solution; C) Hikyaku (*Solanum melongena* × *Solanum integrifolium*) rootstock irrigated with fertilizer solution; D) Non-grafted 'Madonna' (*Solanum melongena* L.) root irrigated with saline solution; E) Taibyou (*Solanum grandifolium* × *Solanum melongena*) rootstock irrigated with saline solution; F) Hikyaku (*Solanum melongena* × *Solanum integrifolium*) rootstock irrigated with saline solution.

The interaction of salinity and rootstocks showed that fresh and dry weight (g) of leaf significantly decreased by salinity and grafted seedling onto Hikyaku was less damaged under the stress conditions as compared to non-grafted seedlings (Table 2).

Table 2. Effect of salinity on grafted and non-grafted seedling leaf

Treatment	Rootstock	Fresh weight (g)	Dry weight (g)	Water content (%)	Leaf number
Interaction effect of salinity and rootstock on leaf					
Control	Non-grafted	14.67 ab	1.16 ab	13.48 ab	6.25 ab
	Taibyou	13.35 abc	1.19 ab	12.19 abc	6.25 ab
	Hikyaku	14.02 abc	1.19 ab	12.82 abc	5.25 b
Salinity	Non-grafted	8.46 c	0.59 c	7.86 c	6.50 ab
	Taibyou	9.36 bc	0.67 bc	8.69 bc	6.25 ab
	Hikyaku	16.56 a	1.31 a	15.25 a	6.50 a
Main effect of salinity and rootstock on leaf					
Control		13.31 a	0.98 a	11.18 a	5.91 a
Salinity		12.16 a	1.06 a	12.25 a	6.41 a
	Non-grafted	13.68 a	1.18 a	12.50 a	6.37 a
	Taibyou	12.02 a	0.95 a	11.08 a	6.25 a
	Hikyaku	12.51 a	0.93 a	11.56 a	5.87 a
Salinity		ns	ns	ns	ns
Rootstock		ns	ns	ns	ns
Salinity × Rootstock		*	*	*	ns
CV		32.22	36.19	32.08	11.47

‡Different letters within the same column are significantly different between means of replications (4 plants in each replication) according to LSD test at $P<0.05$. ‡‡ ns= not significant, * = significant at $P<0.05$, ** =significant at $P<0.001$, ***= significant at $P<0.0001$ ‡‡‡ Non-grafted = *Solanum melongena* L.; Taibyou = *Solanum grandifolium* × *Solanum melongena;* Hikyaku = *Solanum melongena* × *Solanum integrifolium.*

When grown on proper rootstocks, grafted plants have been shown to restrict the transport of Na^+ from the root to the shoot (Goreta et al. 2008, Zhu et al. 2008). The results of current experiment showed that salinity significantly increased Na^+ concentration (mg/g dw) in root, stem and leaves. However, the Na^+ accumulation (mg/g dw) was less in grafted seedlings than non-grafted.

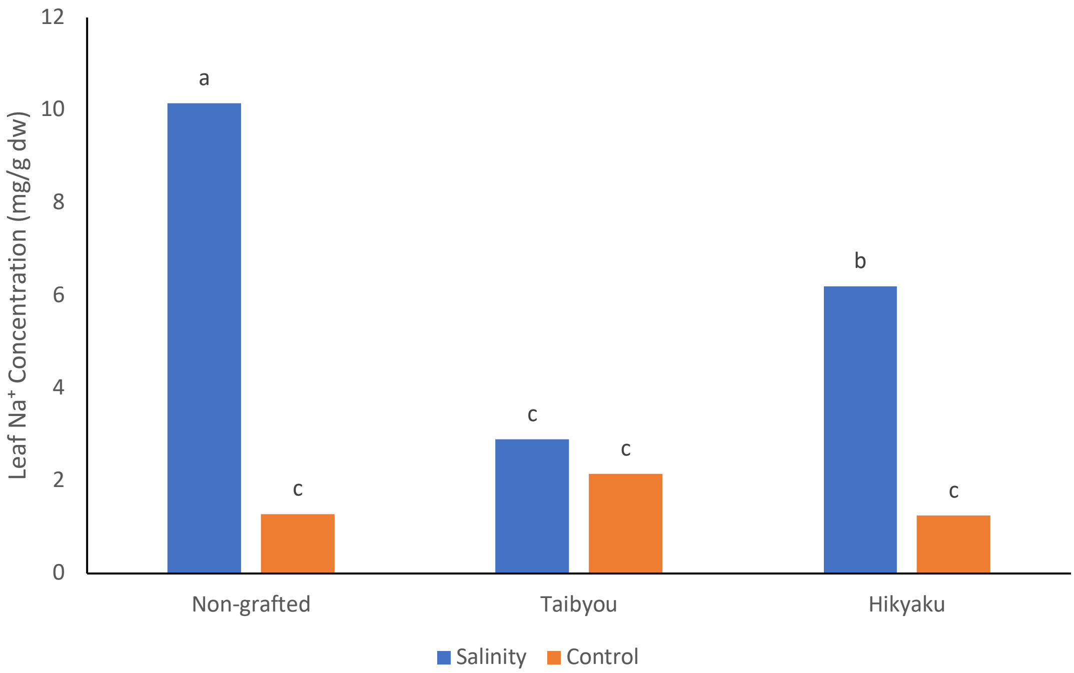

Figure 6. Effect of salinity on grafted and non-grafted seedling leaf Na^+ concentration (mg/g dw)

‡ Bars with different letters indicate significant differences ($P < 0.05$) according to LSD test at $P<0.05$.

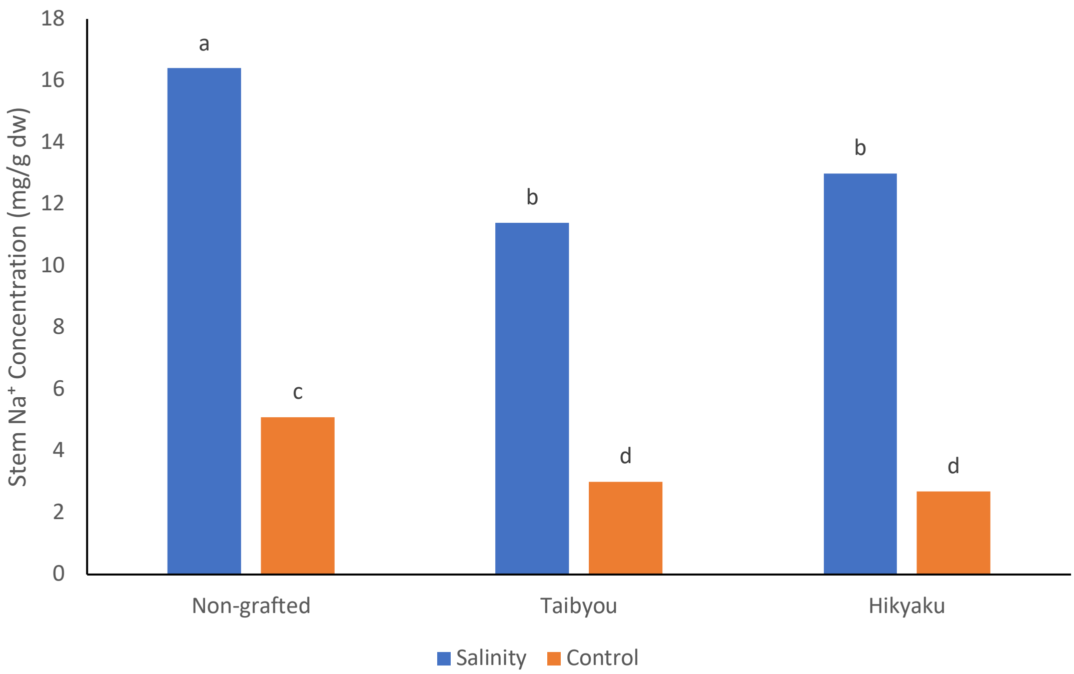

Figure 7. Effect of salinity on grafted and non-grafted seedling stem Na^+ concentration (mg/g dw)

‡ Bars with different letters indicate significant differences ($P < 0.05$) according to LSD test at $P<0.05$.

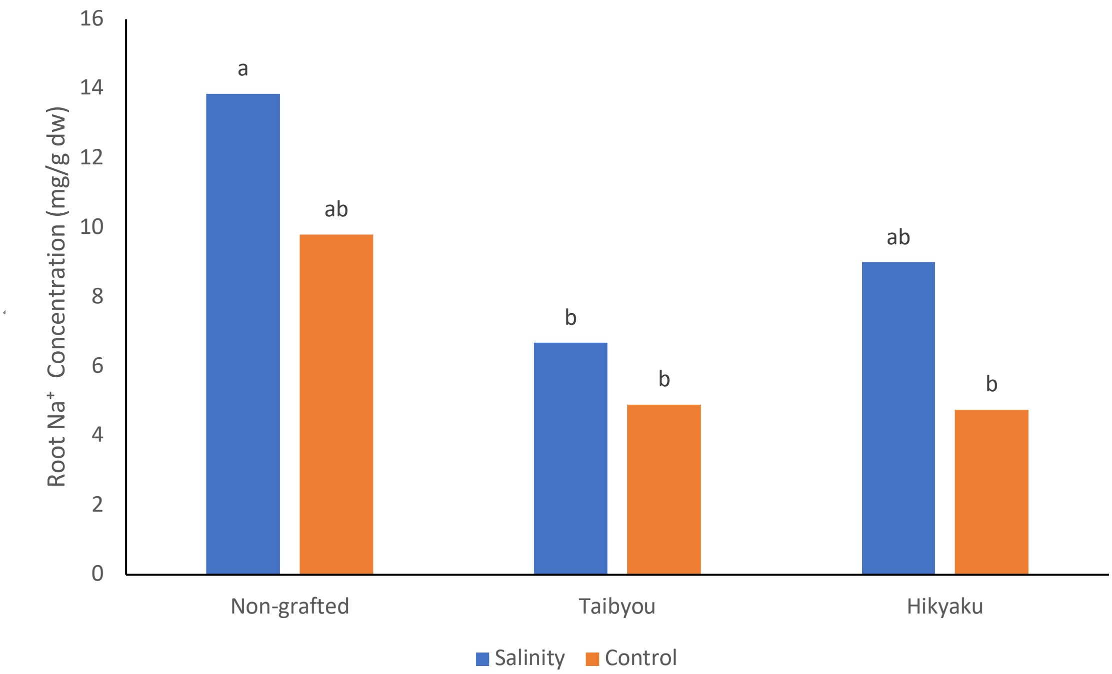

Figure 8. Effect of salinity on grafted and non-grafted seedling root Na^{+} concentration (mg/g dw)

‡ Bars with different letters indicate significant differences ($P < 0.05$) according to LSD test at $P<0.05$.

Sánchez-Rodríguez et al. (2014) reported that increased potassium (K^{+}) concentrations in drought-tolerant tomato rootstock resulted in improved osmoregulation, and the results of potassium concentration (mg/g dw) in leaf and stem showed that no significant differences between the control and salinity treatment and grafted seedling onto Hikyaku accumulated more than non-grafted (Figure 9, 10). Salinity significantly decreased K^{+} concentration (mg/g dw) in the root and grafted seedling on Taibyou was less damaged by the stress (Figure 11).

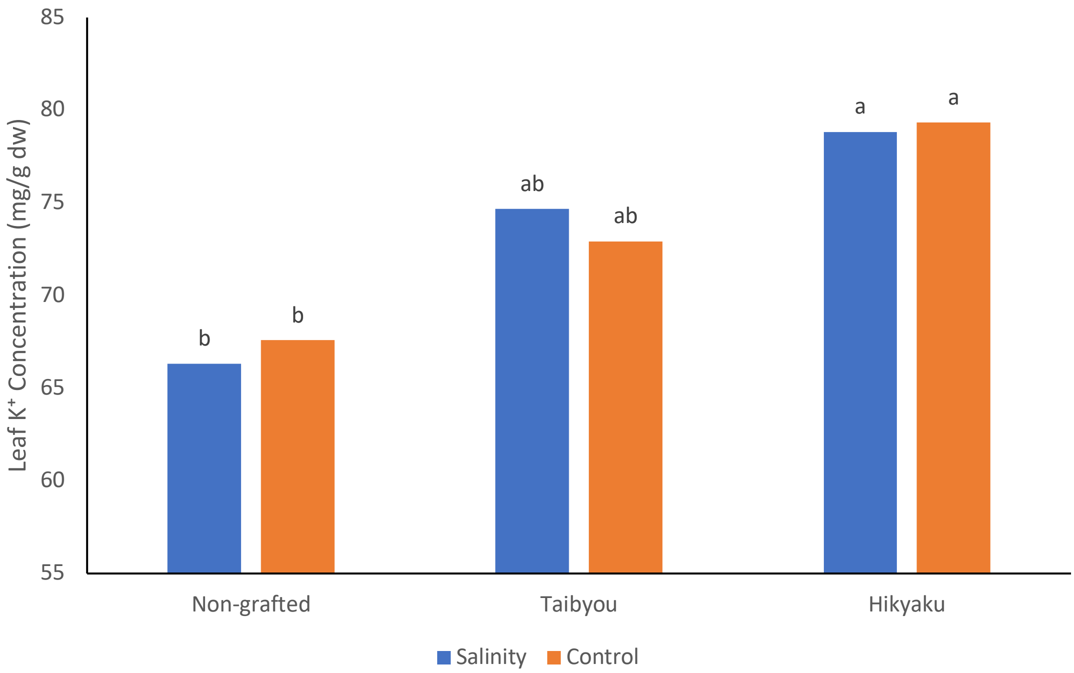

Figure 9. Effect of salinity on grafted and non-grafted seedling leaf K^+ concentration (mg/g dw)

‡ Bars with different letters indicate significant differences (P < 0.05) according to LSD test at P<0.05.

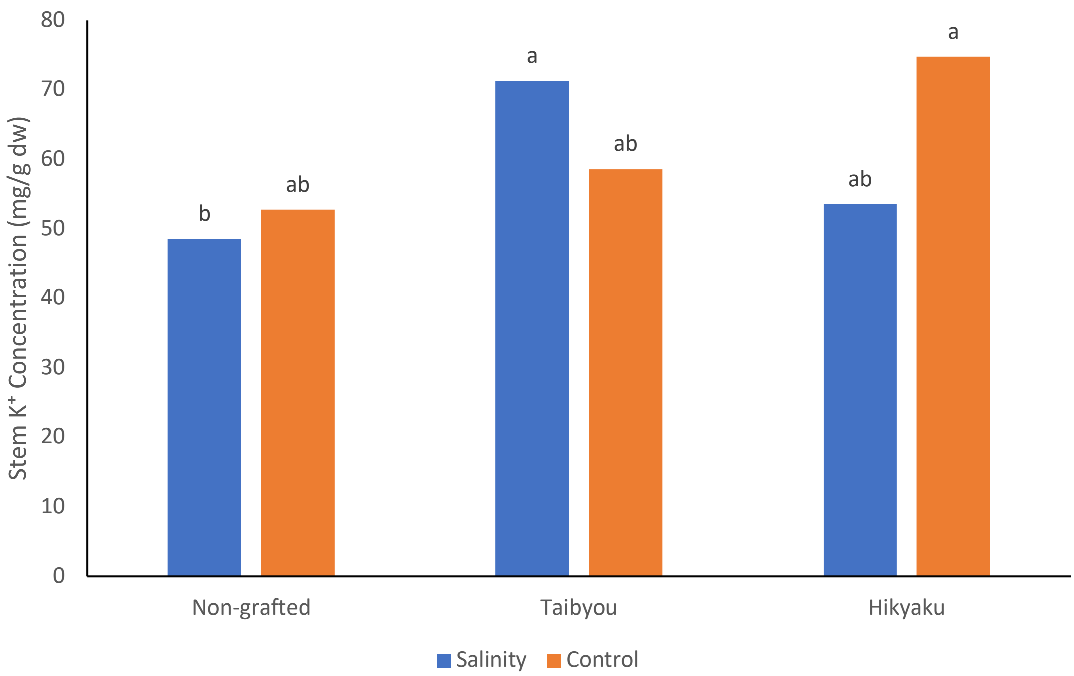

Figure 10. Effect of salinity on grafted and non-grafted seedling stem K^+ concentration (mg/g dw)

‡ Bars with different letters indicate significant differences (P < 0.05) according to LSD test at P<0.05.

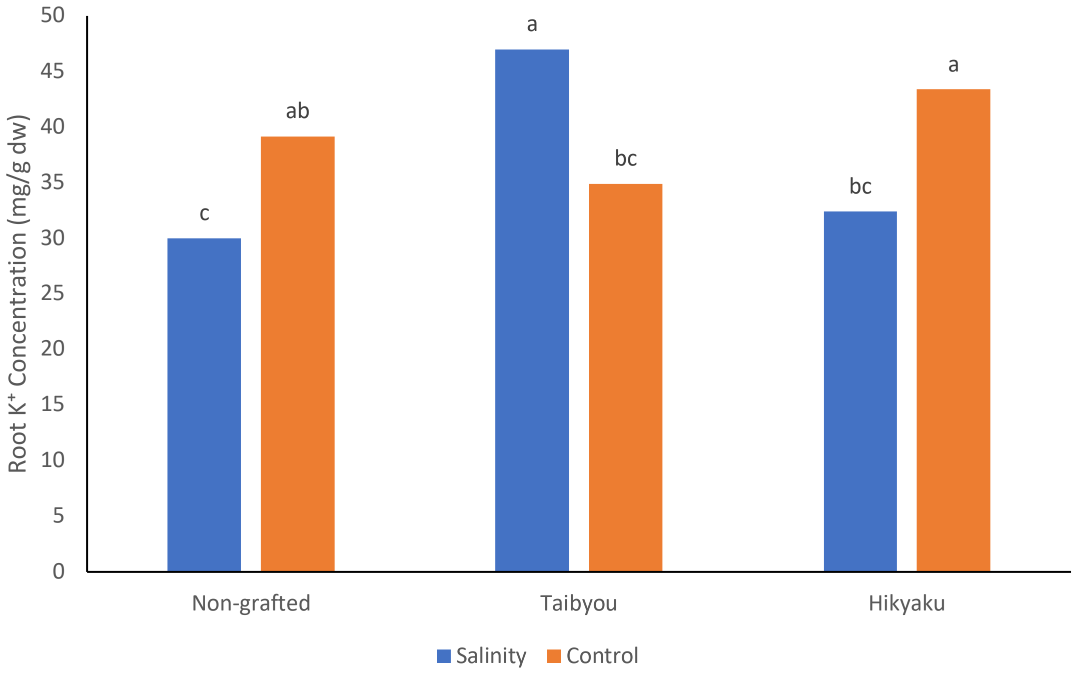

Figure 11. Effect of salinity on grafted and non-grafted seedling root K^+ concentration (mg/g dw)

‡ Bars with different letters indicate significant differences ($P < 0.05$) according to LSD test at $P<0.05$.

The SPAD value significantly decreased in non-grafted seedlings exposed to saline conditions. Hikyaku rootstock was less damaged than the Taibyou rootstock and non-grafted seedlings (Figure 12). Previous findings by Talhouni et al. (2019), and Fernández-García et al. (2002) are comparable to the current study's findings. These findings suggest that grafting can prolong photoinhibition in the presence of salt stress (He et al. 2009).

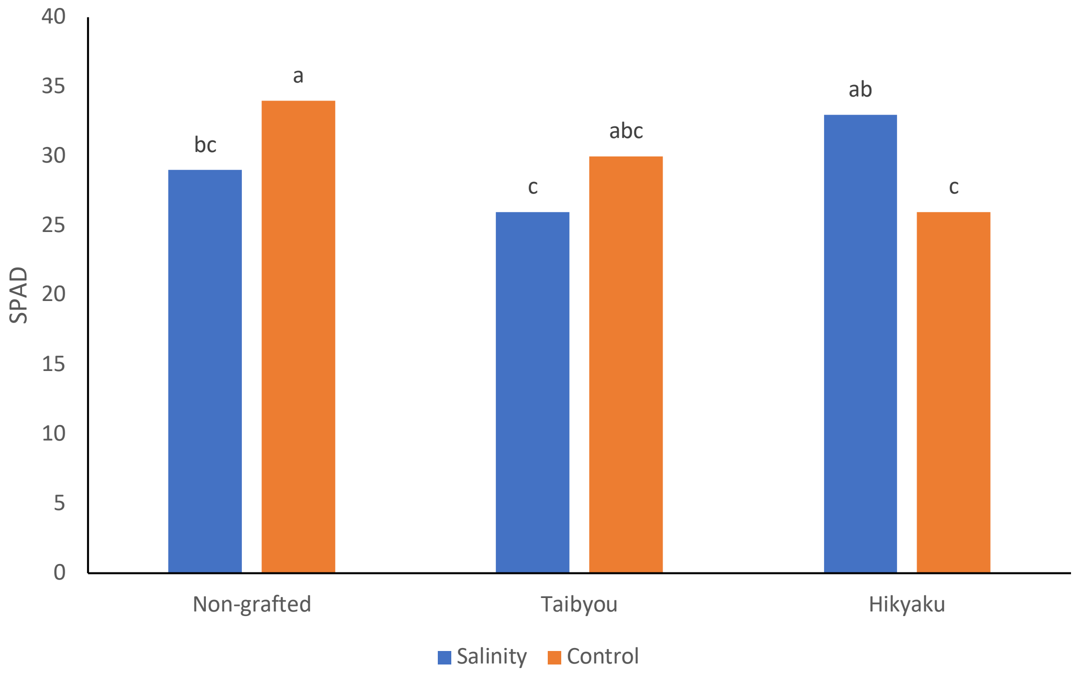

Figure 12. Effect of salinity on grafted and non-grafted seedling SPAD

‡ Bars with different letters indicate significant differences ($P < 0.05$) according to LSD test at $P<0.05$. ‡‡ SPAD: Soil Plant Analysis Development

5. SUMMARY

The present study aimed to investigate the impact of rootstock properties on the performance of grafted plants under salt-stress conditions. The results showed that the root length (cm) and density, root hairs, and root surface area of the rootstock are important factors in regulating salt tolerance in grafted plants. A healthy root system can enhance plant growth and productivity by producing more cytokinin and transporting water to the shoots. The experiment showed that salinity significantly decreased the hair number in non-grafted seedlings, while the root volume and length (cm) was larger in the seedlings grafted onto Hikyaku rootstock. Salinity increased Na^+ concentration (mg/g dw) in root, stem, and leaves, but Na^+ accumulation (mg/g dw) was less in grafted seedlings than non-grafted. Moreover, grafted seedlings onto Hikyaku accumulated more K^+ (mg/g dw) than non-grafted, and salinity significantly decreased K^+ concentration (mg/g dw) in the root. The SPAD value significantly decreased in non-grafted seedlings exposed to saline conditions, but Hikyaku rootstock was less damaged than Taibyou rootstock and non-grafted seedlings. These findings suggest that grafting can prolong photoinhibition in the presence of salt stress.

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Year of publication: 2023

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