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Effect of Foliar Application of Nano-selenium on the Anatomical Characteristics of Date Palm *Phoenix dactylifera* L. Barhi Cultivar under Salt Stress

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Abstract: This study investigated the effect of salinity on the anatomical features of date palm (*Phoenix dactylifera* L.) and the potential roles of nano selenium (Se NPs) in alleviating the adverse effects of salinity. Two concentrations (80 and 160 mg.L^{-1}) of SeNPs were applied as a foliar spray on date palms irrigated with different concentrations of saline water (2.5 [control], 5, 10 and 20 ds.m^{-1}). Results showed that 5 ds.m^{-1} salinity had no significant effect on the anatomical structure of date palm, whether applied alone or in combination with foliar spray of Se NPs. However, the vascular bundle dimensions and thickness of the xylem, phloem and mesophyll were significantly higher in plants exposed to 10 ds.m^{-1} salinity compared with the control plants. In particular, foliar spray of SeNPs at 80 mg.L^{-1} concentration enhanced the effect on these plants. By contrast, 20 ds.m^{-1} salinity significantly reduced all studied parameters except for the thickness of the upper and lower cuticle, which increased. Se NPs at 80 mg.L^{-1} concentration had a significant effect in alleviating the adverse effects of salinity at high levels. The results of this study proved that SeNPs at 80 mg.L^{-1} concentration were more effective in alleviating the adverse effects of salinity on the anatomical structure of date palm leaves than 160 mg.L^{-1} concentration.

Keywords: Barhi date palm, *Phoenix dactylifera* L., Leaf, Vessels, Xylem, Nano-Selenium, Foliar Application, Salt Stress.

Introduction

Date palm (*Phoenix dactylifera* L.) belongs to the Arecaceae family and is a dioecious, perennial, monocotyledonous tree cultivated primarily for its nutritive fruits (Abass, 2013). For over 5000 years, it has played an important role in sustainable agriculture in many countries around the world, including the Middle East and North Africa (Al-Khayri *et al*., 2015). Date palms are exposed to a variety of stress in their natural habitat, including drought, heat, air pollution and salinity (Hazzouri *et al*., 2020). Saline environments present a severe harm to agriculture around the world, owing in part to the irrigation of agricultural fields with salt-containing water. This is common in arid and semiarid environments with high evaporation rates and limited fresh water resources, which require salt leaching into deeper soil layers.

Because of the detrimental effects of salt, appropriate strategies to improve salinity tolerance and reduce the harmful effects of salinity stress need to be employed (Rady *et al*., 2021).

Fathi *et al.* (2017) reported the important roles of nano-fertilisers in reducing salt stress and enhancing crop growth and yield compared with conventional fertilisers. These benefits may be due to the distinctive properties of nanoparticles, as the use of nanomaterials in fertilisation programmes is an effective alternative to traditional fertilisers due to their many advantages, including low cost (Abd *et al*., 2020).

Selenium (Se) is a microelement that is required for plants to function at low concentrations, but it is also toxic to plants at high concentrations (Zhang *et al*., 2006). Se, an important component of selenoprotein, plays diverse biological roles ranging from antioxidant defence to DNA synthesis to reproduction. Various metabolites formed from Se could also play a role in improving tolerance and recuperation, thus slowing down the aging process (Rahmat *et al*., 2017). Se can help plants to not only grow and develop, but also boost their tolerance and antioxidant capacity when they are exposed to various stresses (Pilon-Smits *et al*., 2009). In most cases, the positive impact of Se in plants under stress has been related to enhanced antioxidant activity. Both the organic and inorganic forms of Se in the form of and methyl compounds have been detected in plants (Raza *et al*., 2019). This indicates the essential nature of these micronutrients in plants. Se in low concentrations can act as a wick or initiator to increase plants' ability to withstand different abiotic stresses (Pilon-Smits *et al*., 2009). In studying the effect of Se on the anatomical characteristics of wheat plants subjected to salt stress, Taha *et al.* (2021) found that Se improved the anatomical characteristics of plants as it increased the length and width of vascular bundles, vessel diameters, number of cell layers, diameter and number of sclerenchyma cells, diameter of branches, thickness of the mesophyll and metaxylem, and thickness of the blade and others compared with the control treatment.

Low-dose of Se can stimulate plant growth, improve photosynthesis and help balance essential nutrients (Chauhan *et al*., 2017). Se acts as an anti-aging agent and helps maintain the cytoskeleton and cellular functions, thus contributing to the improvement of plant growth (Kaur *et al*., 2014).

Several morphological and anatomical studies on various plants indicated that leaf tissues were affected and their morphological structure changed (Hmiz & Ithbayyib, 2021) when they were exposed to various abiotic stresses such as salinity (Atabayeva *et al*., 2013; Shareef & Sweed, 2020), heavy metals (Al-Aradi *et al*., 2020) and ultraviolet radiation (Swaid *et al*., 2020). In date palms exposed to abiotic stress, a significant increase in the thickness of the epidermis, endoderm and surrounding stellate was observed, whereas the thickness of the cortex and the diameter of the vascular cylinder, protoxylem and metaxylem decreased significantly.

Heat stress related to salinity or drought stress was more harmful to the anatomical characteristics of date palm than its single effect (Shareef & Sweed, 2020).

Salinity and dryness increased the thickness of the upper epidermis and lower epidermis of the leaf. Alnajjar *et al*. (2020) studied the effect of saline solution at a concentration of 6000 $mg.L^{-1}$ for 60 days. They found that salinity led to a significant decrease in the thickness of the leaf cuticle layer, thickness of the upper and lower epidermis, diameter of bundle sheath cells, fibrous bundles, length and width of vascular bundles, distance between vascular bundles, diameter of primary and secondary xylem, and thickness of leaf phloem.

Moreover, in the root, the thickness of the epidermis and cortex, diameter of vascular cylinder, primary and secondary xylem, and root phloem were decreased. Alapresam *et al.* (2012) found a decrease in the thickness of the mesophyll layer and blade and increased thickness of the cuticle layer and epidermis layer in palms planted in desert areas.

The present work aimed to study the anatomical response of date palm to salinity stress and the potential alleviation of nano selenium (Se NPs) of the adverse effects of salinity.

Materials & Methods

The study was conducted in 2021 in a private orchard of Basrah Governorate, Iraq. The soil of the orchard was clay, and the soil properties were pH = 7.49, EC = 2.43 $ds.m^{-1}$ and CEC = 20.94 cmol/kg, and the soil content of the organic matter was 6.12%. At the age of 6 years, 36 palm trees of the Barhi cultivar were selected. Every three trees were subjected to one of the following treatments:

1. NaCl at 2.5 $ds.m^{-1}$ (control)
2. NaCl at 5 $ds.m^{-1}$
3. NaCl at 10 $ds.m^{-1}$
4. NaCl at 20 $ds.m^{-1}$
5. NaCl at 2.5 $ds.m^{-1}$+ Se at 80 $mg.L^{-1}$
6. NaCl at 5 $ds.m^{-1}$+ Se at 80 $mg.L^{-1}$
7. NaCl at 10 $ds.m^{-1}$+ Se at 80 $mg.L-^{1}$
8. NaCl at 20 $ds.m^{-1}$+ Se at 80 $mg.L^{-1}$
9. NaCl at 2.5 $ds.m^{-1}$+ Se at 160 $mg.L^{-1}$
10. NaCl at 5 $ds.m^{-1}$+ Se at 160 $mg.L^{-1}$
11. NaCl at 10 ds.m-1+ Se at 160 $mg.L-^{1}$
12. NaCl at 20 ds.m-1+ Se at 160 $mg.L-^{1}$

Pure NaCl (HiMedia, India) was used to prepare saline solutions at 2.5, 5, 10 and 20 $ds.m^{-1}$. Se NP solutions were prepared at two concentrations (80 and 160 $mg.L^{-1}$). Every level of salinity was added to soil with irrigation water, whereas Se NP treatments were applied as foliar spray on leaves. Experimental treatments continued for six months. Then, samples were taken to carry out the anatomical study.

Anatomical analysis

The anatomy process was performed according to Willey (1971) .

Statistical analysis

A complete randomised block design was used to design the experiment. SPSS statistical program was used to analyse the data using the least significant difference (LSD) test at 5% probability.

Results & Discussion

Table (1) shows the results obtained from the cross sections (plate 1) of date palm leaves grown under salinity stress and salt stressed trees treated with Se NPs at 80 and 160 $mg.L^{-1}$. The results showed that the upper and lower cuticle thickness of plants exposed to low salinity levels (5 $ds.m^{-1}$) was not significantly affected compared with that of plants exposed to control salinity level (2.5 $ds.m^{-1}$). However, 10 and 20 $ds.m-^{1}$ salinity increased the upper and lower cuticle thickness significantly compared with control, and the largest increase was observed in plants treated with 20 $ds.m^{1}$ salinity. When plants were exposed to 20 $ds.m^{-1}$ salinity, the thickness of the upper cuticle increased from 2.86 µm (control) to 3.91 µm. Also, the lower cuticle thickness increased from 2.63 µm to 3.65 µm. Exogenous application of Se NPs at 80 and 160 $mg.L^{-1}$ resulted in a significant decrease in the upper and lower cuticle thickness compared with 20 $ds.m^{-1}$ salinity treatment The results in table (1) show that the highest thickness of upper and lower epidermis was observed in plants subjected to 10 $ds.m^{-1}$ salinity (11.13 and 10.26 µm respectively), whereas the lowest thickness was observed in plants subjected to 20 ds.m1 salinity (6.16 and 6.50 µm, respectively). In addition, the results revealed that Se NPs at 80 and 160 mg.L-1 concentration significantly reduced the thickness of the upper and lower epidermis when applied as foliar spray on plants exposed to 10 ds.m-1 salt stress compared with those exposed only to salinity stress at the same level. SeNPs at both concentrations increased the thickness of the upper and lower epidermis when combined with 20 ds.m-1 salinity stress compared with 20 ds.m-1 salinity treatment alone.

The results presented in table (2) show that 5 $ds.m^{-1}$ salinity did not affect vascular bundle length significantly compared with control treatment, even when combined with SeNP spraying in the tested concentrations. However, the length of the vascular bundles increased significantly when the plants were exposed to 10 $ds.m^{-1}$ salinity (from 300 µm in the control treatment to 323.33 µm). This increase was even more pronounced (350 µm) when the plants were exposed to 10 $ds.m^{-1}$ salinity and SeNPs at 80 $mg.L^{-1}$ concentration. Furthermore, when exposed to 10 $ds.m^{-1}$ salinity and SeNP spraying, the increase was even more pronounced, reaching 350 µm when at 80 $mg.L^{-1}$ Se NP concentration and 328.33 µm at 160 $mg.L^{-1}$ SeNP concentration. On the contrary, exposure to 20 $ds.m^{-1}$ salinity significantly reduced the vascular bundle length to 251.66 µm, and spraying with SeNPs had no significant effect in mitigating this effect.

Table (1)*: Effect of foliar spray of SeNPs on the upper and lower thicknesses of the cuticle and epidermis of date palm leaves under different levels of salinity stress.*

Treatment	Upper cuticle thickness	Lower cuticle thickness	Upper epidermis thickness	Lower epidermis thickness
NaCl at 2.5 $ds.m^1$ (Control)	2.86 e	2.63 c	8.24 e	7.79 e
NaCl at 5 $ds.m^{-1}$	2.88 e	2.62 c	8.25 e	8.22 d
NaCl at 10 $ds.m^{-1}$	3.05 c	2.65 c	11.13 a	10.26 a
NaCl at 20 $ds.m^{-1}$	3.91 a	3.65 a	6.16 h	6.50 g
NaCl at 2.5 $ds.m^1$ + Se at 80 $mg.L^{-1}$	2.83 e	2.61 c	8.61 d	7.70 e
NaCl at 5 $ds.m^{-1}$ + Se at 80 $mg.L^{-1}$	2.87 e	2.61 c	8.26 e	8.08 d
NaCl at 10 $ds.m^{-1}$ + Se at 80 $mg.L^{-1}$	2.99 cd	2.66 c	9.86 b	9.86 b
NaCl at 20 $ds.m^{-1}$ + Se at 80 $mg.L^{-1}$	3.73 b	3.50 b	7.18 g	7.35 f
NaCl at 2.5 $ds.m^1$ + Se at 160 $mg.L^{-1}$	2.73 f	2.43 d	8.38 de	8.10 d
NaCl at 5 $ds.m^{-1}$ + Se at 160 $mg.L^{-1}$	2.67 f	2.52 d	8.32 e	8.25 d
NaCl at 10 $ds.m^{-1}$ + Se at 160 $mg.L^{-1}$	2.96 d	2.55 d	9.11 c	8.67 c
NaCl at 20 $ds.m^{-1}$ + Se at 160 $mg.L^{-1}$	3.71 b	3.52 b	7.71 f	6.40 g
LSD ($P < 0.05$)	**0.07**	**0.05**	**0.25**	**0.18**

Table (2) also shows the effect of salinity alone or in combination with Se NPs at 80 and 160 mg.L^{-1} concentrations on vascular bundle width in date palm leaves. Salinity at 5 ds.m^{-1}, whether applied alone or in combination with SeNP foliar spray, had no significant influence on vascular bundle width. Meanwhile, when date palms were exposed to 10 ds.m^{-1} salinity, the width of the vascular bundle increased significantly (from 226.33 µm in control plants to 235.33 µm). However, the highest significant value was 251.33 µm, which was obtained when date palm was exposed to this level of salinity and sprayed with SeNPs at 80 mg.L^{-1}. The results also revealed that the width of the vascular bundle in plants exposed to this level of salinity and sprayed with Se NPs at 160 mg.L^{-1} was 234.00 µm. Moreover, this value did not differ significantly from that in plants treated with salinity exposure alone, but it was significantly lower than that in plants treated with Se NP spraying at 80 mg.L^{-1}. The results revealed that plants subjected to 20 ds.m^{-1} salinity had the lowest vascular bundle width of 149 µm, which was significantly lower than those in other treatments. Although Se spraying at 80 and 160 mg.L^{-1} increased the vascular bundle width to 160.33 and 159.66 µm, respectively, these values were significantly lower than those in the control.

The results show that salinity at 5 ds.m^{-1} alone or in combination with Se NPs at 80 or 160 mg.L^{-1} did not significantly affect the thickness of the xylem of vascular bundles of date palm leaves. The xylem thickness was 121.66 µm in control plants, whereas 10 ds.m^{-1} salinity caused a significant increase in the thickness, which reached 131.00 µm. Table (2) shows that foliar spraying of Se NPs at 80 or 160 mg.L^{-1} on plants subjected to 10 ds.m^{-1} salinity had no effect on xylem thickness compared with plants exposed only to the same level of salinity. The xylem thickness decreased significantly in plants subjected to 20 ds.m^{-1} salinity, whether alone or in combination with foliar spraying of Se NPs, compared with control plants. The xylem thickness was 98.33, 111.66 and 108.33 µm in plants subjected to 20 ds.m^{-1} salinity alone or in combination with Se NPs at 80 or 160 mg.L^{-1}, respectively. Plants exposed to 20 ds.m^{-1} salinity and Se NPs had significantly thicker xylem than those exposed to the same level of salinity alone.

Table (2) shows the effect of different levels of salinity, either alone or in combination with Se NP foliar sprays, on the phloem thickness of date palm leaves. Salinity at 5 and 10 ds.m^{-1}, whether applied alone or in combination with Se NPs, had no significant effect on phloem thickness compared with control plants, whereas salinity at 20 ds.m^{-1} significantly reduced the phloem thickness from 57.66 µm in the control plant to 40 µm. Moreover, the results also showed that 20 ds.m^{-1} salinity and 160 mg.L^{-1} Se NPs did not have a significant effect on phloem thickness compared with 20 ds.m^{-1} salinity alone; conversely, Se NPs at 80 mg.L^{-1} had a significant effect, which increased the phloem thickness to 50 µm, and this average did not differ statistically with the average phloem thickness in comparison plants.

Fig. (1) shows that the average mesophyll thickness of date palm leaves in control plants was 321 µm, which did not differ significantly from the average mesophyll thickness of control plants sprayed with Se NPs at 80 and 160 mg.L^{-1} (321.66 and 325 µm, respectively).

Table (2): Effect of foliar spray of SeNPs on the vascular bundle traits of date palm leaves under different levels of salinity stress.

Treatment	Vascular bundle length	Vascular bundle width	Xylem thickness	Phloem thickness
NaCl at 2.5 ds.m^{1} (Control)	300.00 c	226.33 c	121.66 c	57.66 abc
NaCl at 5 ds.m^{-1}	302.66 c	222.33 c	120.00 cd	56.00 abc
NaCl at 10 ds.m^{-1}	323.33 b	235.33 b	131.00 ab	60.00 abc
NaCl at 20 ds.m^{-1}	251.66 ef	149.00 f	98.33 d	40.33 d
NaCl at 2.5 ds.m^{1} + Se at 80 mg.L^{-1}	298.33 c	224.00 c	119.33 c	62.33 ab
NaCl at 5 ds.m^{-1} + Se at 80 mg.L^{-1}	308.33 c	221.33 c	122.33 bc	55.00 bc
NaCl at 10 ds.m^{-1} + Se at 80 mg.L^{-1}	350.00 a	251.33 a	133.33 a	65.00 a
NaCl at 20 ds.m^{-1} + Se at 80 mg.L^{-1}	261.66 e	160.33 e	111.66 d	50.00 c
NaCl at 2.5 ds.m^{1} + Se at 160 mg.L^{-1}	281.66 d	222.66 c	124.33 abc	53.33 c
NaCl at 5 ds.m^{-1} + Se at 160 mg.L^{-1}	308.33 c	219.33 d	121.00 c	55.00 bc
NaCl at 10 ds.m^{-1} + Se at 160 mg.L^{-1}	328.33 b	234.00 b	126.66 abc	58.33 abc
NaCl at 20 ds.m^{-1} + Se at 160 mg.L^{-1}	250.00 f	159.66 f	108.33 d	43.33 cd
LSD ($P < 0.05$)	**11.07**	**6.70**	**9.26**	**8.83**

Salinity at 5 ds.m^{-1}, alone or in combination with foliar spray of Se NPs, had no effect on mesophyll thickness compared with the control treatment. Meanwhile, mesophyll thickness increased significantly in plants exposed to 10 ds.m^{-1} salinity alone or in combination with foliar spray of Se NPs at 80 or 160 mg.L^{-1} compared with control plants, which were 334.33, 393.33 and 338.33 µm, respectively. Notably, mesophyll thickness was increased significantly in plants exposed to 10 ds.m^{-1} salinity and 80 mg.L^{-1} Se NPs compared with those that were sprayed with 160 mg.L^{-1} Se NPs and those that were exposed only to salinity. Conversely, 20 ds.m^{-1} salinity alone or in combination with Se NPs resulted in a significant reduction in mesophyll thickness compared with the control treatment. The mesophyll thickness of plants exposed to 20 ds.m^{-1} salinity alone or in combination with Se NPs at 80 or 160 mg.L^{-1} was 238.33, 300 and 305 µm, respectively.

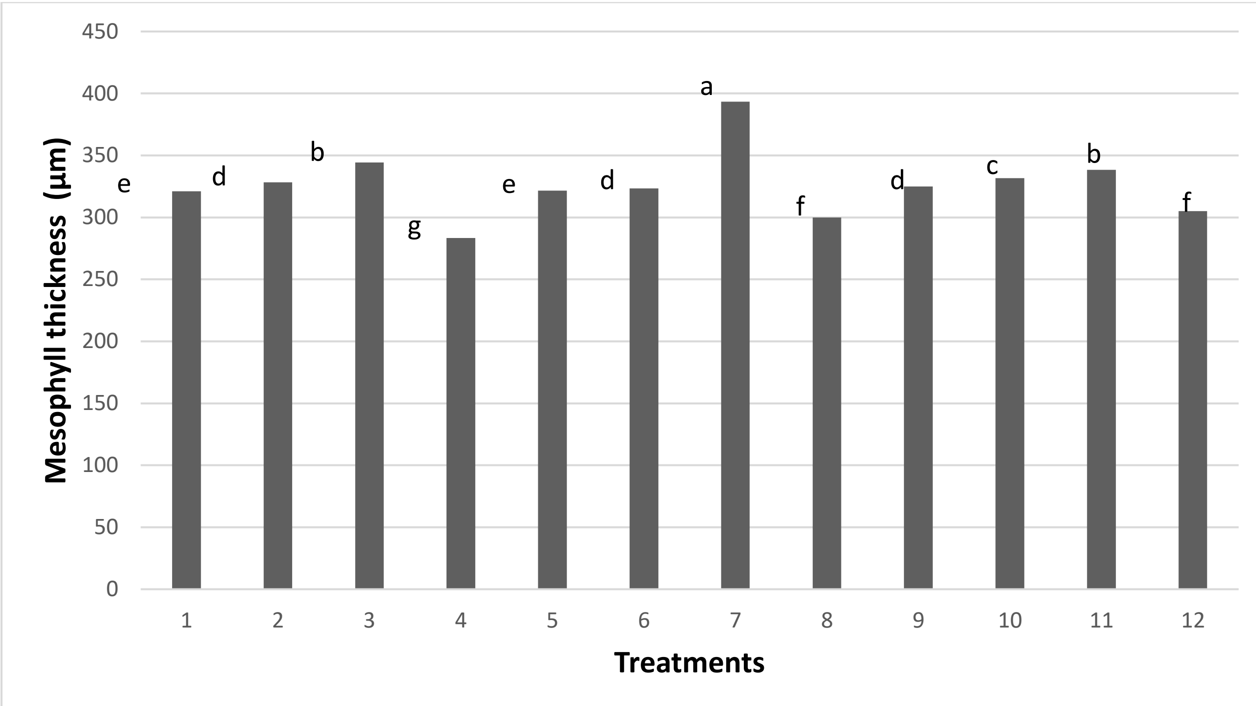
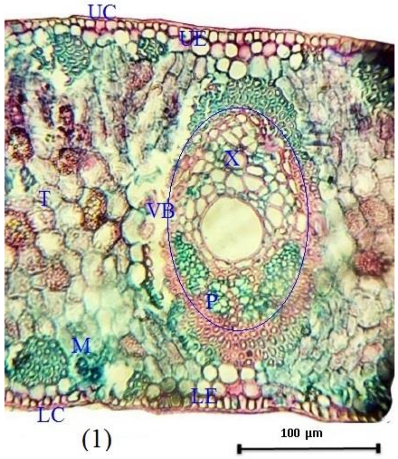


Fig. (1): Effect of foliar spray of SeNPs on the mesophyll thickness of date palm leaves under different levels of salinity stress.

According to the findings, spraying 80 or 160 mg.L^{-1} Se NPs on plants exposed to 20 ds.m^{-1} salinity had a significant effect on increasing the thickness of the mesophyll compared without spraying. For this trait, no significant differences were observed between 80 and 160 mg.L^{-1} Se NPs when applied as a foliar spray with 20 ds.m^{-1} salinity. In the present study, the effect of increasing salinity levels on the anatomical structure of date palm leaves and the potential role of Se NPs in alleviating the toxic effects of salinity stress were examined. The results showed that, except for cuticle thickness, moderate salinity (10 ds.m^{-1}) resulted in an increase in the epidermal thickness, vascular bundle dimensions, conductive elements and mesophyll thickness. Meanwhile, high salinity level (20 ds.m^{-1}) led to a decrease in all studied traits, except cuticle thickness, which increased. The metabolism of plants, as well as their anatomy and morphology, is known to be affected by salinity. These alterations are frequently thought to be adaptations that help the plant withstand salt stress; nevertheless, they might also be signs of harm and disturbance of the regular balance of life processes (Poljakoff-Mayber, 1975). Salts hinder plant growth in a variety of ways, including reducing a plant's ability to absorb water in saline soils. The signs of osmotic stress are quite similar to drought stress.' Even when there is water in the soil, these symptoms, which are similar to drought stress, exist (Chang *et al*., 2020). Hameed *et al.* (2009) stated that the vascular bundle dimension increases under moderate salinity (up to 15 $ds.m^{-1}$) and decreases at high salt level, which is consistent with the results of this study. The findings of this study, which showed that the anatomical structure of salt-exposed date palm leaves was affected, are in accordance with those of Alnajjar *et al*. (2020) and Shareef & Sweed (2020). The results of this study showed that plants exposed to 20 ds.m-1 salinity and Se NPs (either at 80 or 160 $mg.L^{-1}$) have the lowest upper and lower cuticle thickness compared with those exposed only to salinity. However, they were significantly thicker than control plants. The same trend of results was observed for the thickness of both epidermis layers. Regarding vascular bundle dimensions and conductive elements, the application of Se NPs as a foliar spray at 160 $mg.L^{-1}$ had no significant effect on all traits when combined with 20 ds.m-1 salinity compared with salinity treatment alone. However, the application of Se NPs as a foliar spray at 80 $mg.L^{-1}$ had only a significant effect on vascular bundle width and phloem thickness. The same trend of results was also observed for mesophyll thickness.

The results of mesophyll thickness showed the same trend. Despite the fact that Se is not regarded as a necessary element for higher plants, metabolism or nutrition, several studies have shown that low concentrations of Se have stimulating effects on plants, particularly when they are under abiotic stress (Golubkina *et al*., 2019; Khalofah *et al*., 2021). Se NPs have recently been employed as a foliar spray to protect plants from extreme stress by enhancing antioxidant defence systems (Djanaguiraman *et al*., 2018). The effects of Se NPs may vary depending on environmental circumstances or plant species, as well as the size, shape and concentrations of NPs used (Etesami *et al*., 2021). As a result, NP concentration, size, treatment technique, absorption by plants, characteristics, reactivity and translocation into different tissues might all influence whether they interact with various metabolic functions, resulting in toxic or beneficial effects (Paramo *et al*., 2020). This could explain why 80 $mg.L^{-1}$ Se NPs had a more significant effect than 160 mg.L-1 Se NPs, and their effectiveness was more pronounced when combined with 10 $ds.m^{-1}$ salinity.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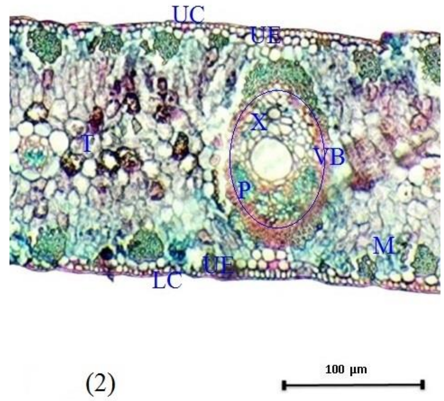
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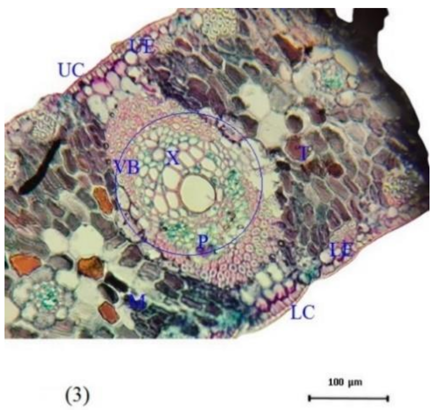
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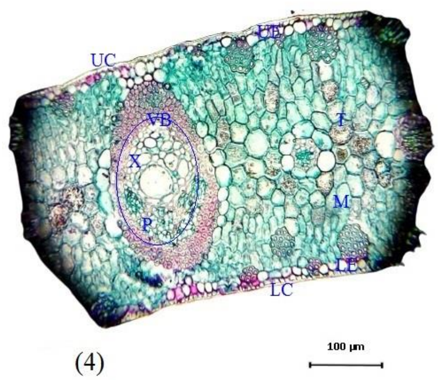
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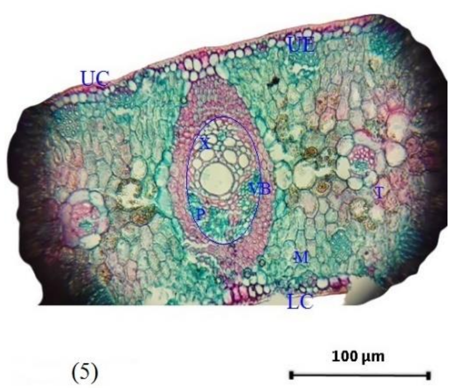
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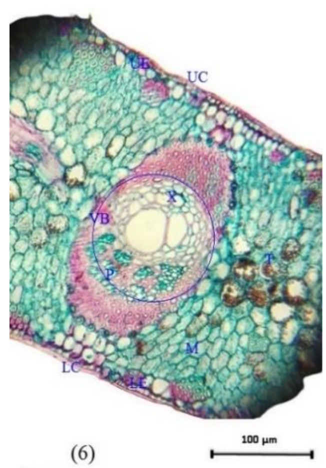
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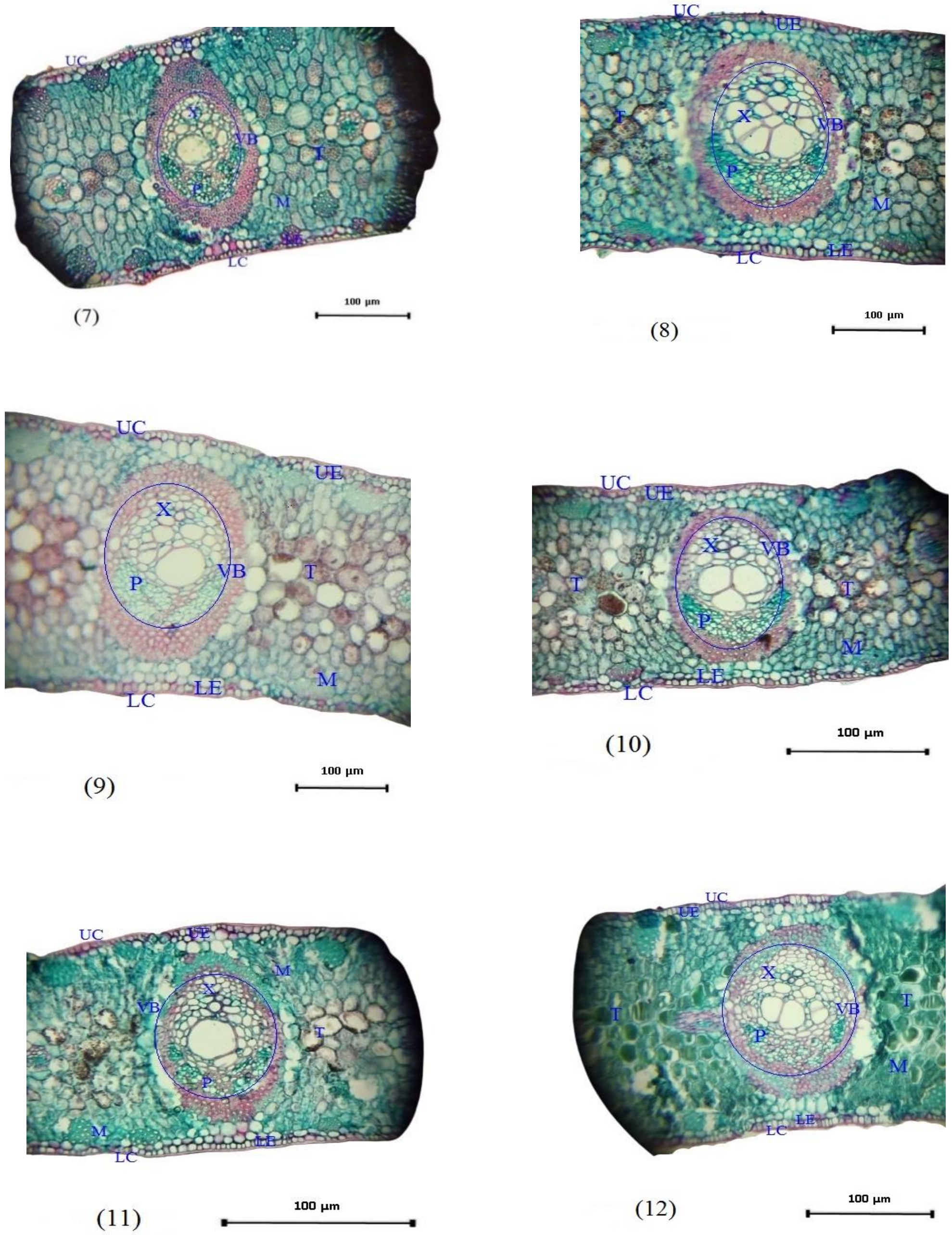

Fig. (2): Cross sections of Date palm leaves treated with salinity and Se NPs. (1) salinity at 2.5 ds.m^{-1}; (2) salinity at 5 ds.m^{-1} (3) salinity at 10 ds.m^{-1} (4) salinity at 20 ds.m^{-1} (5) salinity at 2.5 ds.m^{-1} + Se NPs at 80 ppm (6) salinity at 5 ds.m^{-1} + Se NPs at 80 ppm (7) salinity at 10 ds.m^{-1} + Se NPs at 80 ppm (8) salinity at 20 ds.m^{-1} + Se NPs at 80 ppm (9) salinity at 2.5 ds.m^{-1} + Se NPs at 160 ppm (10) salinity at 5 ds.m^{-1} + Se NPs at 160 ppm (11) salinity at 10 ds.m^{-1} + Se NPs at 160 ppm (12) salinity at 20 ds.m^{-1} + Se NPs at 160 ppm. Abbreviations: LC. Lower Cuticle; LE. Lower Epidermis; M. Mesophyll; P. Phloem; T. Tannin; UC. Upper Cuticle; UE. Upper Epidermis; VB. vascular Bundle; X. Xylem.

Conclusion

Se NPs had a positive effect on many of the anatomical characteristics of date palm, which help mitigate the harmful effects of salinity. Moreover, they changed the anatomical structure of the palm tissue to help it withstand salt stress. The effect of 80 $mg.L^{-1}$ Se NPs was better than that of 160 $mg.L^{-1}$ Se NPs in most of the anatomical characteristics, and treatment with 10 $ds.m^{-1}$ salinity + 80 $mg.L^{-1}$ Se NPs had the best effect on most of the studied traits amongst all other treatments.

Contributions of authors

A.S.M.: Carried out the experiment and data collection.

A.M. A.: Analysis and interpretation of results.

K. M.A.: Write the manuscript.

All authors reviewed the results and approved the final version of the manuscript.

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Conflicts of interest

The authors declare that they have no conflict of interests.

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تأثيرتطبيق الرش الورقي للسلينيوم النانوي على الصفات التشريحية لنخيل التمر *Phoenix dactylifera* L. صنف البرحي المجهد ملحياً

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المستخلص: أجريت هذه الدراسة لمعرفة تأثير الملوحة على الخصائص التشريحية لنخيل التمر (*Phoenix dactylifera* L.) والأدوار المحتملة للسيلينيوم النانوي في التخفيف من الآثار الضارة للملوحة. تم إضافة السيلينيوم النانوي رشاً على الأوراق بتركيزين (80 و 160 ملجم/ لتر$^{-1}$) على نخيل التمر المروي بمياه مالحة بتركيزات مختلفة (2.5: كمعاملة مقارنة 5، 10، و 20 ديسي دسيمنز.متر$^{-1}$). أظهرت النتائج عدم وجود تأثير معنوي للملوحة عند تركيز 5 ديسي سيمنز.متر$^{-1}$ على التركيب التشريحي، سواء تم تطبيقه بمفرده أو مع الرش الورقي لـ السيلينيوم النانوي. ومع ذلك، كانت أبعاد الحزمة الوعائية وسمك الخشب واللحاء والميزوفيل أعلى بشكل معنوي في الأشجار المعرضة للملوحة عند 10 ديسي سيمنز.متر$^{-1}$ مقارنة بمعاملة المقارنة، وكذلك أدى الرش بمحلول السيلينيوم النانوي بتركيز 80 ملجم. لتر$^{-1}$ على الأشجار إلى تعزيز هذه الزيادة في الصفات المذكورة. في المقابل، أدت الملوحة عند 20 ديسي سيمنز.متر$^{-1}$ إلى انخفاض معنوي في جميع الصفات المدروسة باستثناء سمك الطبقة العلوية والسفلية من البشرة التي زاد سمكها. بينما كان لـ السيلينيوم النانوي بتركيز 80 ملجم.لتر$^{-1}$ تأثير معنوي في التخفيف من آثار الملوحة عند المستويات العالية. أثبتت نتائج هذه الدراسة أن تركيز السيلينيوم السيلينيوم النانوي عند 80 ملجم.لتر$^{-1}$ كان أكثر فاعلية في التخفيف من الآثار الضارة للملوحة عند تركيز 160 ملجم.لتر$^{-1}$ على التركيب التشريحي لأوراق النخيل.

الكلمات المفتاحية: نخيل البرحي، الأوراق، الأوعية، الخشب، نانو سيلينيوم، تطبيق الرش الورقي، الإجهاد الملحي