Enhancement of Cucumber Growth by Nanofertilizers Seed Priming under Salinity Conditions

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ABSTRACT

Salinity stress has a harmful effect on almost all cucumber growth stages especially germination stage. For this, nutrient seed priming in nanofertilizers may be a promising approach to cope the deleterious effects of salinity on plant growth and development. The present study aimed to evaluate the effect of cucumber seed priming in synthesized nanofertilizers under salt stress conditions. Cucumber (*Cucumis sativus. L*) seeds were primed in fresh water, bulkfertilizers of (NPK), and nanofertilizers (50%, 25%, and 12.5%) as a percentage of bulk fertilizers. Five salinity levels (freshwater: sea water) (0.7, 2.5, 5, 7.5, and 10dSm^{-1}) were used to irrigate seedlings for 7 days. Obtained results revealed that increasing salinity levels significantly diminished radicle and plumule lengths, seedling fresh and dry weights, germination percentage, radicle surface area, radicle length reduction/ increase (RLR%), salt tolerance and vigor index. In contrast, the radicle radius was increased. Priming seeds in nanofertilizers improved percentage of seed germination, lengths of radicle and plumule seedlings, fresh and dry weights of seedlings, radicle surface area, RLR%, salt tolerance, and vigor index, while decreased radicle radius compared to fresh water and bulk fertilizers. Occurred results lead to concluded that, priming seeds in nanofertilizers decreased the harmful effect of salinity and it was successful technique in alleviating salt stress in cucumber seedlings through germination stage.

Keywords: germination; nanofertilizers; radicle radius; salt stress; vigor index; seed priming

INTRODUCTION

Climate change is an important phenomenon that threats the world nowadays. It causes ocean level rise and subsequently affect coastal regions. Soil salinity is one of the impacts of global warming. About 7% of the world's total land region, 20% of the cultivated soil around the world and almost 50% of the world's irrigated lands are affected by salt stress (Zhu. 2001). Most plants can't tolerate high salts concentrations or can withstand just with a reduction in productivity (Zhang and Shi. 2013). In Egypt, especially the Nile Delta region is considered the most affected area by increasing salinity levels which occupy about 30% areas of the delta lands (2.0Mha) (Mohamed. 2016). The main causes of salinity in salt- influenced soils are expansion of the Mediterranean coast, limited freshwater resources, high temperature and evaporation, and saline water logging (Shalaby and Gad. 2012), which threat world food security.

Cucumber (*Cucumis sativus. L*) is considered one of the most important economic vegetable crops. It has high nutritional value. It is sensitive to salt stress where the productivity affected clearly under high levels of salinity. It is widely cultivated in greenhouse during winter and in open field during summer season. Cucumber is very commonly cultivated and consumed fresh and pickled all around the globe and mostly in Egypt (FAO. 2017).

Nutrient seed priming is the most feasible, low-risk and cost-effective method in which seeds are primed in nutrient solutions rather than fresh water to enhance the nutrients content of seed. Priming improves seed quality for better germination, seedling stabilization (Ajouri et al. 2004) and induces several physiological, biochemical, and molecular changes. It stimulates stress responsive genes associated with germination (Kubala et al. 2015). To mitigate the negative impacts of abiotic stresses like salinity, Khan et al. (2009) stated that seed priming of hot pepper with KNO_3 or $CaCl_2$ increased proteins, free amino acids and soluble sugars during germination under salt and water stress condition. Acid phosphatase and phytase enzyme activities in the cotyledons, roots and shoots of lettuce under stress were increased by seed priming of KNO_3 (Nasri et al. 2011).

Nanotechnology has provided the opportunity of discovering nanoscale or nano-structured materials as fertilizer carrier or controlled-release vectors for structuring of the so-called smart fertilizers. The nanomaterials and fertilizers enhance the nutrient use efficiency and diminish the expense of environmental pollution (Chinnamuthu and

Boopati. 2009). In addition to that nanofertilizers are promising an alternative of traditional fertilizers to ensure high crop production and soil restoration. The nanoparticles uptake can promote the reactive oxygen species (ROS) production, acting in different metabolic pathways, increase the level of active gibberellins, and the mobilization of storage proteins (Chandrasekaran et al. 2020). In addition, Joshi et al. (2018) demonstrated that the impact of nanoparticles in increasing seed water uptake can cause sufficient stress to activate seed germination. Nanopriming of seeds increases the access of nutrients and water to plants, accelerates the expansion of leaf area, and thus increases the use of light energy for plant growth. It is an effective way to reduce the amount of fertilizer applied to crops (do Espirito Santo Pereira, A., et al 2021).

In this context Kasote et al. (2019) produced iron nanoparticles using onion extract. His study declared that priming watermelon seeds in the nano-iron improved germination and increased the growth of its shoots and roots. The bulk iron ($FeCl_3$ and Fe_2O_3) caused adverse antioxidant and chlorophyll effects compared to the nanoparticles. Ye et al. (2020) mentioned that modulating sodium distribution between shoots and roots could be the reason for alleviating salinity for jalapino pepper when it primed in manganese nanoparticles. It also, enhanced germination and root elongation under salt stress. Abdel- Latef et al. (2017) illustrated that priming Lubin seeds in zinc nanoparticles improved photosynthetic pigments and all growth parameters and could alleviate the negative effect of salinity stress. Maswada et al. (2018) stated that treated sorghum seeds with nano iron increased chlorophyll content and enhanced germination under salt stress.

A new trend so-called smart fertilizers which facilities to enhance the nutrient efficiency and diminish the expense of environmental pollution (Chinnamuthu et al. 2009). Within this framework, we hypothesized that priming in synthesized NPK nanofertilizers may be effective in strengthening salt tolerance during the early seedling stage. It would improve the production of protective compounds and osmotic adjustment for increasing the growth parameters. The importance of NPK in plant growth and productivity is well established but the role of using its nanoparticles in alleviation salinity stress is still not clear. Therefore, the aim of this study is to test the effectiveness of priming in synthesized-nanofertilizers solutions in alleviating the harmful impact of salt stress on seed germination of cucumber plants.

MATERIALS AND METHODS

The present study consists of two main experiments. Both experiments were conducted at the Soil Fertility & Plant Nutrition Laboratory, Department of Soil and Water, Faculty of Agriculture, Alexandria University, Egypt. The first experiment intended with the synthesis of NPK nanoparticles and the characterization of the final outcomes using Scanning electron microscope (SEM) and Energy dispersive X- ray (EDX). While, the second experiment aimed to study the effect of seed priming on germination of cucumber seeds under salinity stress by using bulk and synthesized nanofertilizers.

1. Synthesis of Nitrogen nanofertilizer:

Commercially available zeolite was procured from the Delta Biotic Company. The Zeolite samples were dried at 80ºC overnight ground and sieved with a 100- mesh screen before use. Synthesis of nanofertilizers was completed in two steps:

(a) Synthesis of Surfactant Modified Zeolite (SMZ)

Banishwal et al. (2006) method for surfactant modification of the zeolite (SMZ) was carried out using hexadecyltrimethyl ammonium bromide (HDTMABr) (200mg/L). As the surfactant is the only source of carbon in the system, the surfactant loading was monitored by total organic carbon (TOC) analysis of the initial and final solutions obtained during the synthesis of SMZ.

(b) Synthesis of Nitrogen nanofertilizer

Required quantities (~170 g) of SMZ were stirred with 1.0 M solution of $(NH_4)_2SO_4$. The amount of nitrogen incorporated, was calculated from the difference of the quantities of this element in the unmodified zeolite and that in the synthesized zeolite (Banishwal et al. 2006).

2. Synthesis of Phosphorus Nanofertilizer

Hydroxyapatite nanoparticles were synthesized, using a wet chemical technique with 0.4 mole of diammonium hydrogen phosphate and 0.6 mol of calcium nitrate tetra hydrate precursors, respectively. The pH of the system was kept at 10.8 throughout the stirring process. The prepared powder was used for further characterization. This precipitation reaction for synthesis of hydroxyl-apatite nanoparticles was first proposed by Yagai and Aoki, as indicated by Arunseshan et al. (2013).

3. Extraction and preparation of Potassium nanofertilizer from banana peels

Potassium nanofertilizer was extracted from banana peels using potassium hydroxide (20 g) as extracting agent at optimum operating conditions (1:2 solid to liquid ratio, temperature 100 °C, and cooking time 30 min). The cold slurry was exposed to vacuum filtration to obtain clear brown filtrate and thick dark brown sludge. Then, the clear filtrate was heated to about 70 °C, with continuous stirring at 300 rpm. Urea and citric acid (5% solution) were added dropwise until reaching pH 5 (Hulbert. 2014, Hussein et al. 2019).

4. Characterization of NPK synthesized-nanoparticles

The surface morphology, composition and element contents of the synthesized- nanofertilizers were investigated using scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) respectively. The characterization processes were done at the Central Lab of Faculty of Science, Alexandria University, Egypt.

5. Experimental layout

The studied treatments in this experiment consist of two factors; the first one is priming of cucumber seeds with NPK bulkfertilizers or nanofertilizers, while the second factor is the addition of different salinity levels to the cucumber seedlings. Cucumber seeds (*Cucumis sativus cv. Madaen F1*) were first sterilized using 3% H_2O_2 solution and thoroughly washed with distilled water. The sterilized seeds were divided into five groups for priming with various solutions T_1 (NPK bulkfertilizers bFs) according to (Haifa, 2020) 0.163 g/L of urea, 0.371 g/L of super phosphate and 0.1087 g/L of potassium sulphate, T_2, T_3 and T_4 were priming in the previously synthesized NPK nanofertilizers (nFs) which represent (50%, 25%, and 12.5% as a percentage of the NPK bulkfertilizers) and control T_5 which was seed soaking in fresh water. The seeds were primed for 24 hours once at the beginning of the experiment and then left for naturally drying. Each seed group was divided again into five groups which represent 5 levels of salt equivalent including (0.7, 2.5, 5, 7.5 and $10 dSm^{-1}$). The germination experiments were run in a completely randomized design with three replications at 25^0C. The germination experiments were carried out in petri dishes with two round filter papers moistened with 5 ml distilled water and 10 ml solutions of different salinity levels for 7 days. All growth parameters were measured for all seedlings at the end of the experiment after 7 days.

Measurement of Physiological Parameters

a. Growth parameters

Radicle and plumule lengths were determined by the method described by Tennant (1975). The fresh weight and volume of shoots and roots of the seedlings were measured immediately after 7days, the dry weight of roots and shoots were estimated after drying the shoot and root at 80°C for 48 h.

b. Germination percentage (GP)

The rise of plumule is taken as a sign of germination process. The percentage of germination was determined using the following equation: Germination percentage (%) = (Number of germinated seeds / Number of total seeds) *100.

C. The vigor index (VI)

The formula of Elouaer and Hannachi (2012) was used for calculation of VI as follows: Vigor index (VI) = [seedling length (cm) × germination percentage%] /100.

d. Radicle radius and surface area

According to the method of Hallmark and Barber (1984), average radicle radius of seedling was determined from $r = (V/\pi\ L)^{1/2}$, where r = average radicle radius, V = radicle volume, and L = radicle length. Radicle surface area (RSA) was calculated from $RSA = 2\pi rL$.

e. Radicle length reduction/increase (RLR):

RLR was determined as follow: RLR= $((RL\ at\ S_x - RL\ at\ S_0)/ RL\ at\ S_0)*100$, Where RLS_0 is the length of radicle at control; RLS_x is the length of radicle at different salinity levels.

f. Salt tolerance Index (STI):

STI was determined according to Fathi and Gaafar. (2015):

Salt tolerance index (%) = (FWt at $_{Sx}$ /FWt at $_{S0}$) *100, Where FWt = the fresh weight of seedling, S_0 = tap water, S_x = at different five concentration of sea water.

6. Statistical Analysis

The experiment design was Complete Randomized Design (CRD). Experimental data were analyzed by COSTAT software package 6.311 for variance analysis. Treatment means were compared using Newman Kauls test at $p \leq 0.05$ probability level.

RESULTS

3.1. Preparation of nanofertilizer

Nanozeolite was examined in the laboratory prior to the synthesis of nanofertilizer. After evaluating some physical properties of the zeolite, the surfactant was modified. A correction was confirmed with an increase in organic carbon percentage (from 1.7% to 3.3%). The initial nitrogen content of the zeolite (0.34%) was very low, but increased to 1.82% after the synthesis of nanofertilizer. This confirms that the fertilizer components were successfully incorporated into the modified zeolite (Banishwal et al. 2006). Also the concentration of phosphorus in synthesized-Hydroxyapatite nanoparticles was 21.76%, and potassium concentration extracted from banana peels was 10% according to Hussein et al. (2019) study.

2. Characterization of synthesized-nanofertilizer

The structure of surface morphology and elemental analyses of nitrogen nanofertilizer were examined using SEM and EDX analyses are shown in Figure 1(a,b) respectively. The SEM image clearly showed different shapes and different sizes of nitrogen nanofertilizer lie in the nanostructure range (1-100) nm. The EDX analysis revealed the elemental composition of nitrogen nanofertilizer. They are potassium, calcium, silicon, iron, sulphur, aluminum, and nitrogen elements in addition to carbon and oxygen. The SEM image of the prepared hydroxyapatite nanoparticles shows the spherical shaped particles lie in the nanoscale range (1-100) nm. The EDX spectrum of prepared nano-hydroxyapatite illustrates the percentage of calcium, phosphorus, chloride, and oxygen in hydroxyapatite nanoparticles (Arunseshan et al. 2013) as shown in Figure 1(c,d). The SEM analysis of potassium nanofertilizer indicates that nanospherical structure particles were obtained with size ranged from 21 to 30 <100 nm. The standard EDX spectra recorded on the examined potassium nanofertilizer shows the presence of potassium, silicon, chloride, and oxygen Figure 1(e,f).

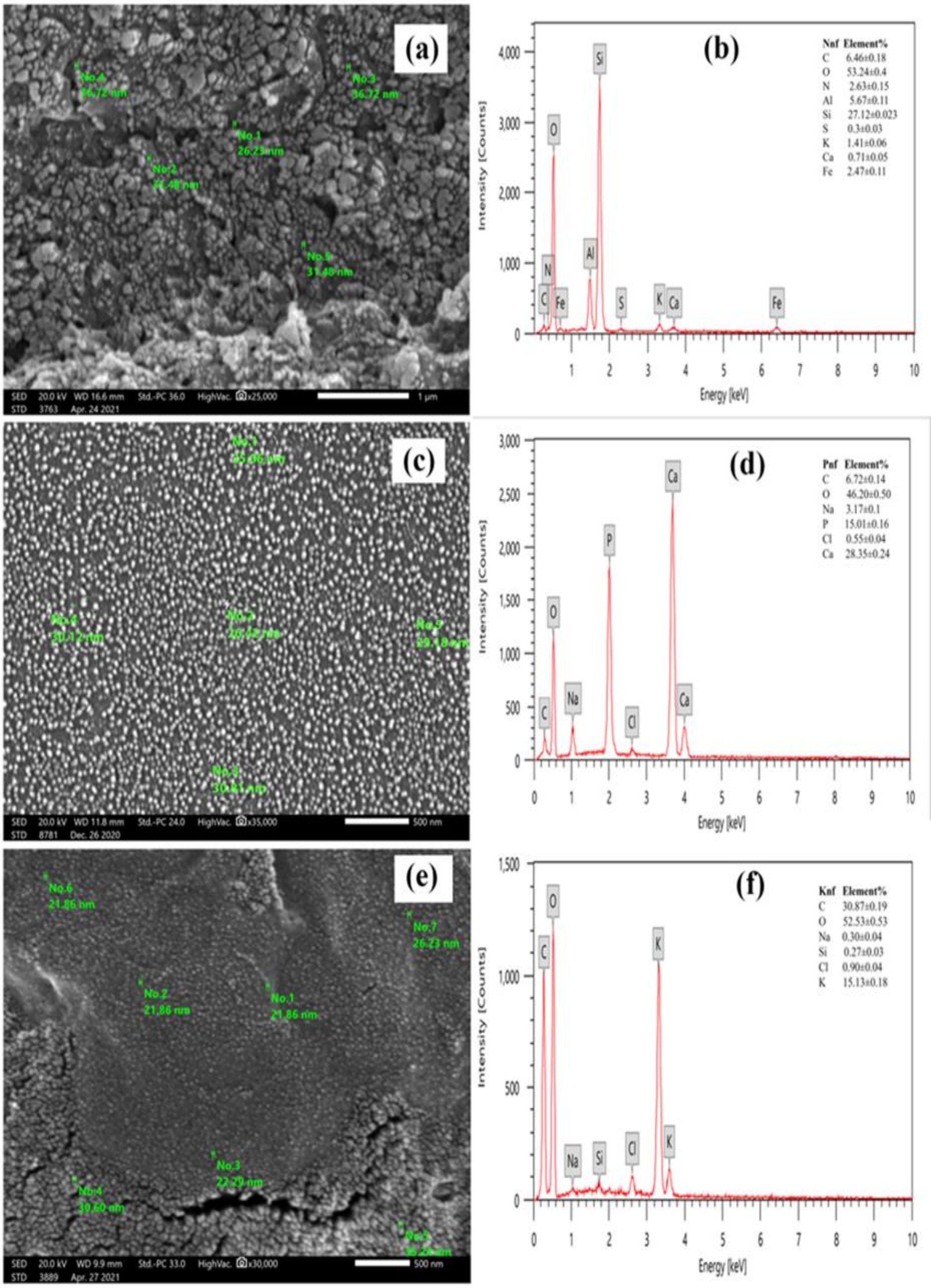

Figure 1: Scanning electron microscopy (SEM) image (a,c,e), energy dispersive X-ray (EDX) (b,d,f) of nitrogen (Nnf), phosphorus (Pnf), and potassium (Knf) nanofertilizers respectively

3. Effectiveness of nanofertilizers priming solution on alleviating the adverse effect of salt stress.

3.1. Growth Parameters

The effect of seed priming on cucumber growth parameters (radicle length, plumule length, fresh and dry weights) under salt stress is shown in Table 1. In general, grown seedlings without salt stress were healthier and more vigorous than those grown under salt stress. In all priming treatments, increasing salinity levels significantly ($P \leq 0.05$) reduced radicle length, plumule length, fresh and dry weights of cucumber seedling. However, the deleterious effect of salt stress was less pronounced in 50% nFs- primed seedlings than FW and bFs primed seedlings as shown in Figure 2. For example, the fresh weight of cucumber seedling significantly increased from 1.09 g at bFs to 2.08 g at 50%nFs under the highest salinity level (10dSm^{-1}).

3.2. Germination percentage (GP)

The germination percentage of cucumber seeds under salt stress affected by different priming treatments is presented in Table 1. Germination percentage decreased gradually with increasing salinity levels. Seeds germination was greatly inhibited (60%) at the salinity level of 10 dSm^{-1} although seeds were primed with FW. Meanwhile, the germination percentage at 10 dSm^{-1} salinity level was significantly improved when seeds were primed with nanofertilizers. Priming seeds with nanofertilizers had significant beneficial effects on germination performance of cucumber seeds under salt stress.

Table 1: The effect of seed priming in five different treatments on cucumber growth parameters (radicle length, plumule length, fresh and dry weights, Germination percentage) under salt stress

Treatments Salinity Levels dSm^{-1}	Priming Treatments	Growth Parameters: Radicle Length (cm)	Plumule Length (cm)	Total Fresh Weight (g)	Total Dry Weight (g)	Germination Percentage (%)
0.7	FW	15.56 ±0.83e	8.91±0.17bc	1.77±0.04e	0.119±0.003b	100±0.00 a
	bFs	19.89±0.15b	9.00±0.29b	1.86±0.09d	0.120±0.006b	93.33±2.89 b
	50% nFs	27.42±1.49a	9.35±0.09a	2.71±0.06a	0.135±0.003a	100±0.00 a
	25% nFs	18.45±0.03c	9.03±0.08b	2.47±0.07b	0.101±0.003c	93.33±2.31b
	12.5% nFs	16.54±0.70d	8.25±0.43c	2.22±0.07c	0.098±0.001c	90±0.00bc
2.5	FW	14.83±0.39d	8.40±0.23a	1.70±0.00d	0.107±0.007b	88.67±2.31bc
	bFs	12.56±1.07b	8.50±0.29a	1.85±0.09c	0.110±0.006b	90.67±0.00 b
	50% nFs	20.31±0.47a	8.68±0.11a	2.65±0.15a	0.126±0.001a	100±0.00 a
	25% nFs	16.08±0.05c	8.56±0.25a	2.25±0.09b	0.094±0.001c	90±5.77 b
	12.5% nFs	17.85±0.90e	6.83±0.19b	1.87±0.07c	0.093±0.012c	85±2.89c
5	FW	12.81±0.40c	7.58±0.19b	1.67±0.10c	0.093±0.001c	85±2.89bc
	bFs	15.50±0.58b	8.31±0.18a	1.74±0.00bc	0.100±0.006b	88.67±2.31b
	50% nFs	17.50±1.44a	8.45±0.21a	2.49±0.05a	0.120±0.006a	93.33±1.15 a
	25% nFs	12.98±0.16c	7.73±0.01b	1.84±0.02b	0.090±0.001d	85.33±2.89 bc
	12.5% nFs	11.95±0.32d	6.50±0.29c	1.75±0.03b	0.085±0.003e	80±0.00c
7.5	FW	10.53±0.13b	7.02±0.08b	1.64±0.14b	0.088±0.001c	80±2.89a
	bFs	6.70±0.12d	6.50±0.58c	1.13±0.04e	0.096±0.005b	75±2.89b
	50% nFs	12.93±0.10a	7.75±0.14a	2.34±0.15a	0.115±0.003a	80±5.54a
	25% nFs	10.04±0.32c	6.63±0.36c	1.49±0.12c	0.086±0.001c	76.66±5.77ab
	12.5% nFs	10.31±0.02c	5.35±0.20d	1.33±0.08d	0.081±0.000d	75.3±2.89b
10	FW	6.81±1.05c	5.63±0.36c	1.59±0.05b	0.075±0.001c	60±5.77d
	bFs	6.25±0.14cd	6.25±0.43b	1.09±0.05e	0.082±0.001b	75±2.89b
	50% nFs	11.92±0.34a	7.25±0.14a	2.08±0.04a	0.093±0.001a	80±0.00a
	25% nFs	9.05±0.49b	6.25±0.14b	1.44±0.12c	0.080±0.001b	75±2.89b
	12.5% nFs	7.27±0.73c	4.60±0.35d	1.30±0.04d	0.078±0.002bc	70±5.77c

FW: Fresh Water; bFs: bulkfertilizers; nFs: nanofertilizers; Means of column under each subheading ± standard error (n = 3) followed by different letters (a–e) are significantly different ($P \leq 0.05$). Values followed by the same letter in the same column are not significantly different ($P \leq 0.05$).

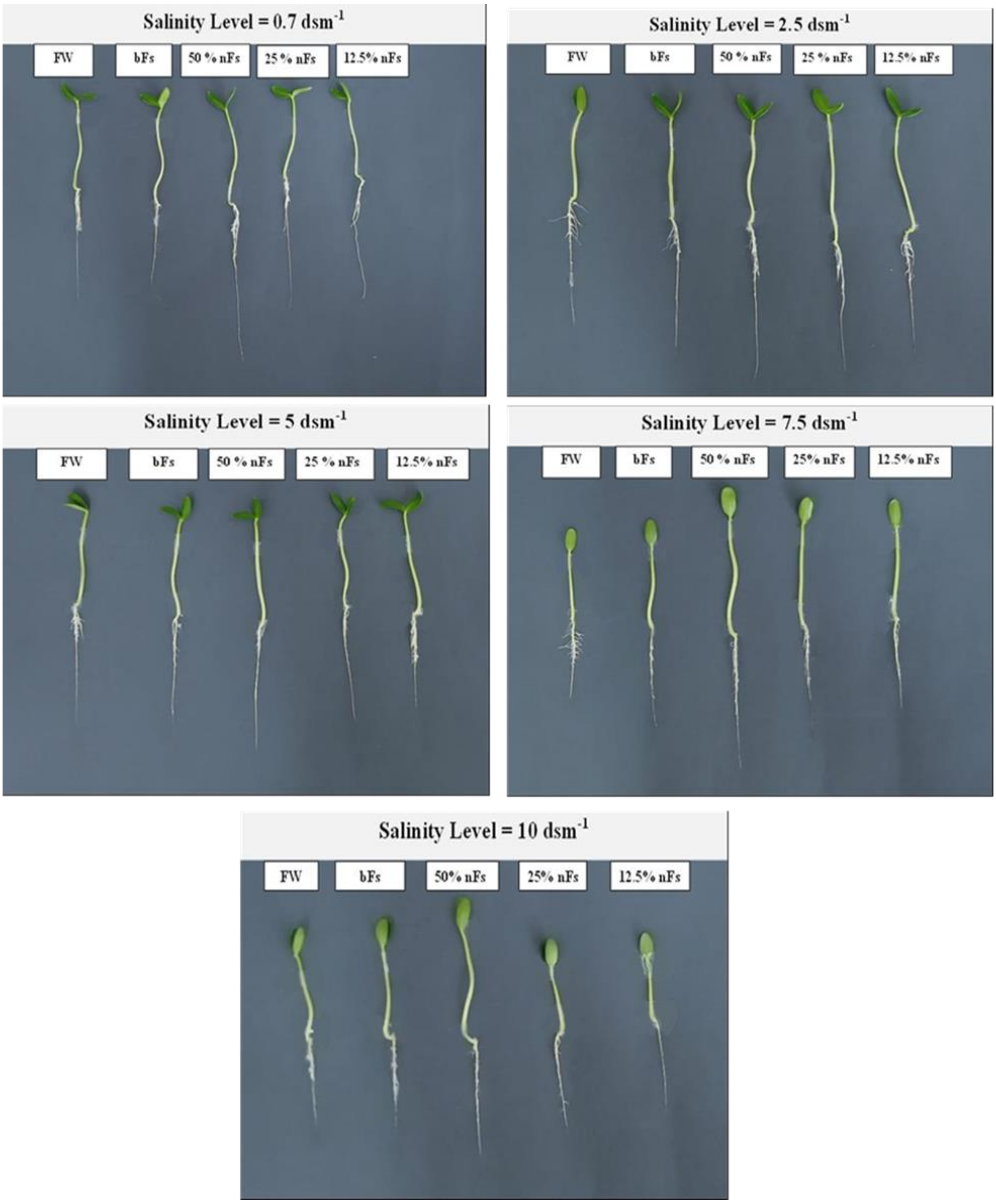

Figure 2: Comparison between the effect of priming in fresh water (FW), bulkfertilizers (bFs), and different ratios of nanofertilizers (nFs) on seed germination, radicle and plumule lengths of cucumber seedlings under salt stress.

3.3. Radicle Length Ratio (reduction /increase (RLR %)

Salinity stress had a significant inhibitory effect on radicle length of cucumber seedlings for all priming treatments Figure 3. Reduction in the length of radicle at high salinity conditions significantly pronounced by soaking in various ratios of nanofertilizers. However, this adverse effect was diminished in seedlings primed in 50% nanofertilizers in comparison with fresh water and bulkfertilizers.

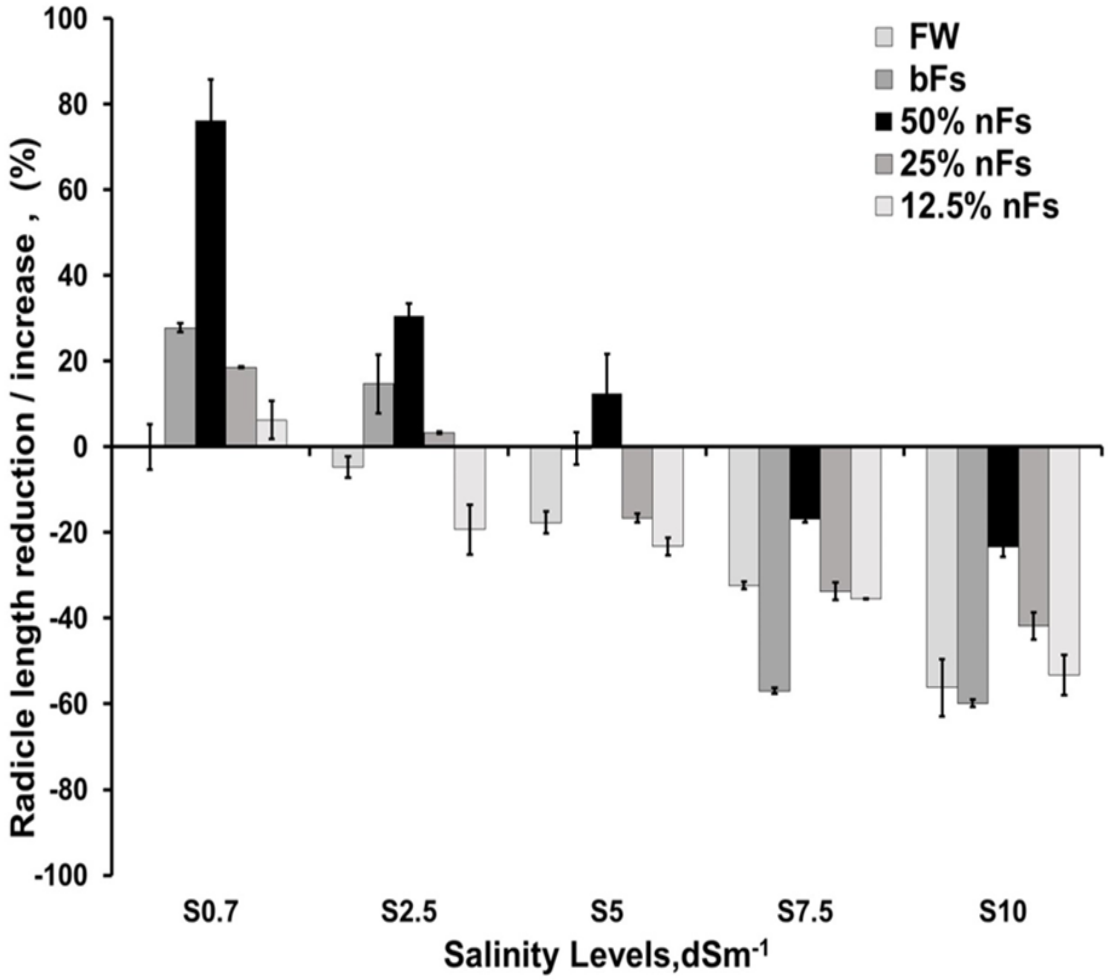

Figure 3: Effect of seed priming with five different priming solutions on radicle length reduction /increase (%) of cucumber seedlings under different salinity levels. Bars are standard error (n = 3), L.S.D=5.38 for priming factor at Significance Level (0.05).

3.4. Radicle radius (RR) and radicle surface area (RSA):

The impact of priming treatments on radicle radius (RR) of cucumber seedling at various salinity levels is displayed in Figure 4(a). The RR of cucumber seedling showed a significant variation under different salt concentrations in all priming treatments. In general, the highest RR was observed at highest salt concentration 10dSm^{-1}. Priming in nanofertilizers with different concentrations significantly diminished the RR, but 50% nFs priming treatment had the best effect at which a significant decrease in RR. Additionally, the impact of priming treatments on radicle surface area (RSA) of cucumber at various salinity levels is shown in Figure 4(b). The RSA of cucumber seedling for nFs priming treatments was significantly increased at different salt concentrations comparing with seeds primed in bFs and fresh water. Therefore, the results indicated that soaking the cucumber seeds in various concentrations of nanofertilizers (50%, 25% and 12.5%) significantly increased the RSA, and the highest RSA was observed at 50% nFs.

3.5. Salt tolerance (STI) and vigor indices (VI)

Increasing salinity levels caused reduction in STI and VI of cucumber seedlings for all priming treatments as displayed in Figure 5(a,b). The highest values for STI and VI were noticed at 0.7 dSm^{-1} and the least value of salt tolerance and vigor indices at 10 dSm^{-1}. In general, seed priming of cucumber in different ratios of nanofertilizers significantly ($p < 0.05$) raised the STI and VI at all salinity levels, but the 50% nFs achieved the best soaking treatment. So, the priming in nanofertilizers produced seedlings having a higher tolerance to salinity conditions than fresh water and bulkfertilizers priming treatments.

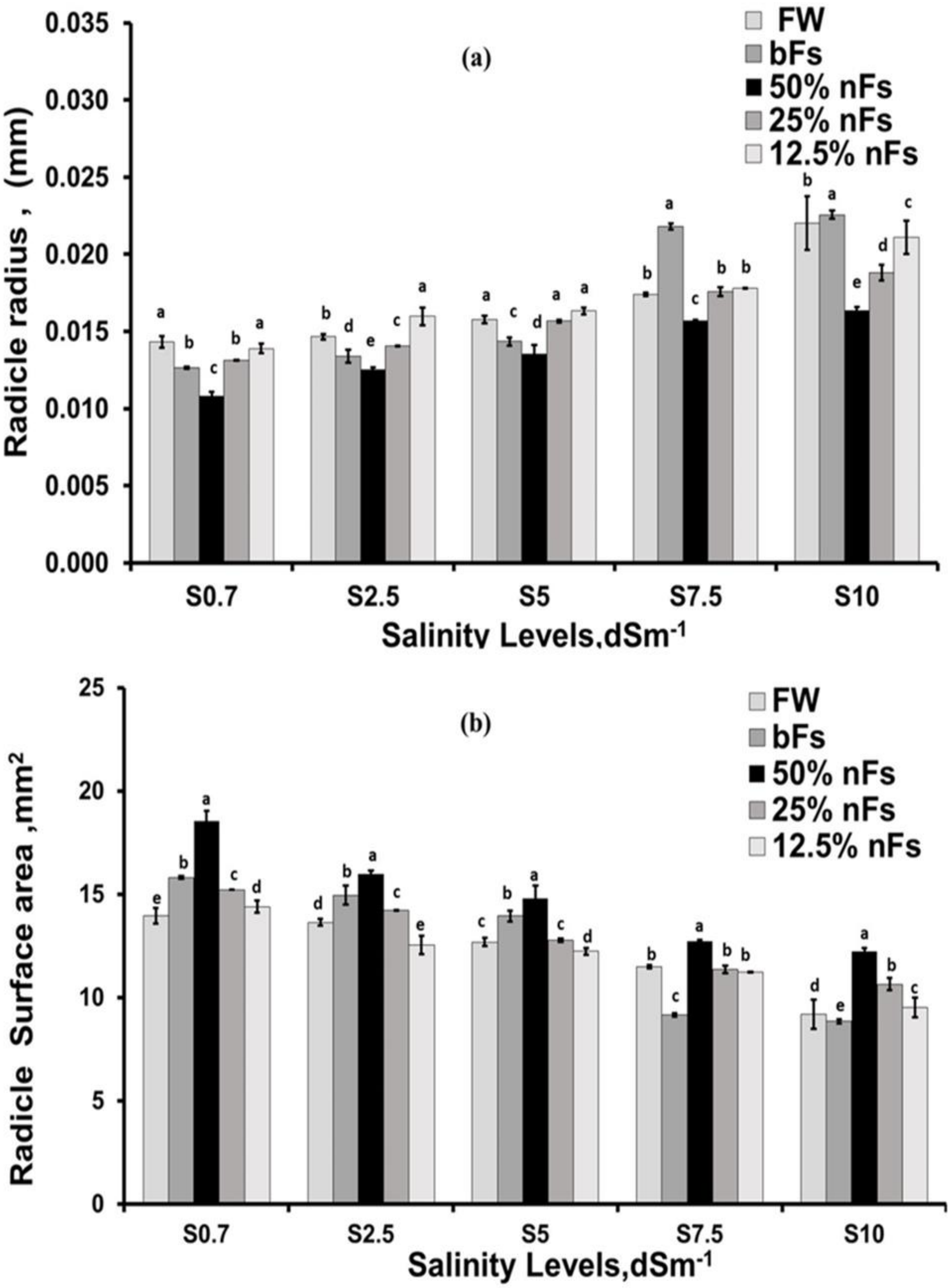

Figure 4: Effect of seed priming with five different priming solutions on (a) radicle radius (mm) and (b) radicle surface area (mm^2) of cucumber seedlings under different salinity levels. Letters represent statistically significant differences between the means at ($p \leq 0.05$), Bars are standard error (n = 3).

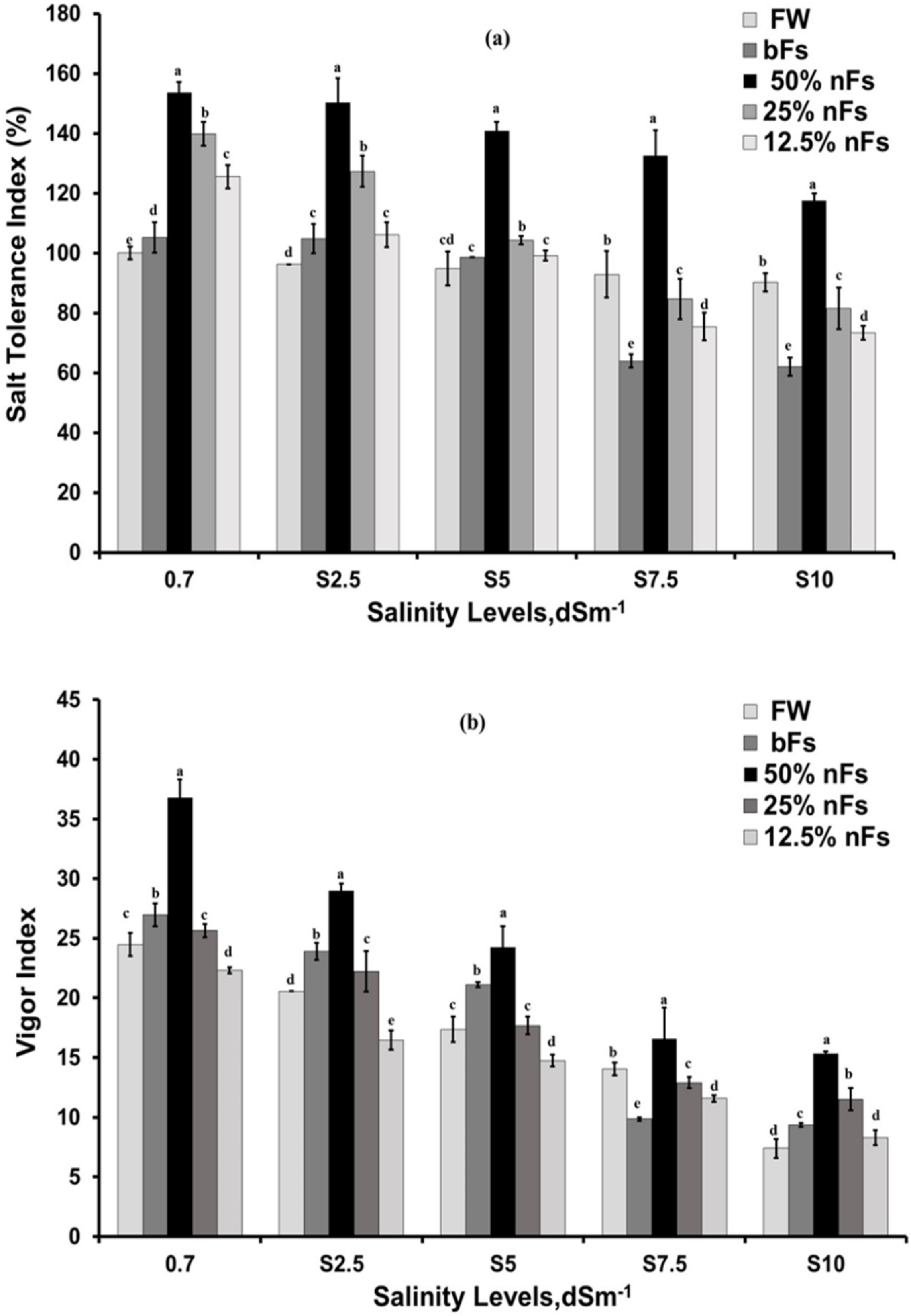

Figure 5: Effect of seed priming with five different priming solutions on (a) salt tolerance, (b) vigor indices of cucumber seedlings under different salinity levels. Letters represent statistically significant differences between the means at ($p \leq 0.05$), Bars are standard error (n = 3).

DISCUSSION

1. Synthesis and characterization of NPK nanofertilizers

The SEM images indicated that synthesized NPK nanofertilizers were in the range of nano-structure (1-100 nm). The EDX analysis also, indicated the presence of nitrogen, phosphorus and potassium in all samples Figure 1. Moreover, the analysis of NPK synthesized nanofertilzers indicated that N, P, and K concentrations were 1.82%, 21.76% and 10% respectively.

2. Growth Parameters

Increasing salinity stress significantly reduced radicle length, plumule length, fresh and dry weights of cucumber seedling. In a previous study of Farooq et al (2015) postulated that the deleterious effect of salt stress on plant growth could be due to sodium and chloride ions toxicity and the disturbance of biosynthesis and plasma membrane integrity. Also the decrease in seedling fresh and dry weights at high salt stress because of the reduction in water availability resulted from high osmotic potential and increase concentrations of Na^+ and Cl^- ions (Ibrahim. 2016). In present study priming in nanofertilizers especially 50%nFs had a significant effect ($p \leq 0.05$) on all traits including radicle length, plumule length, fresh and dry weights of cucumber seedlings comparing to bulkfertilizers, and fresh water primed seeds. During priming, the embryo expands and compresses the endosperm. The compressive strength of the embryo and the hydrolytic activity of the endosperm cell wall can change the tissue to create flexible, free space during dehydration and promote rapid germination of seedlings after rehydration (Mohammadi. 2009). The results of present study were in accordance with the results of Khan et al. (2009) who demonstrated that soaking pepper seeds in NaCl significantly influenced and further developed plumule and radicle lengths. Additionally the increment of total biomass observed in cucumber seedling produced from seeds primed in nFs agreed with Kasote et al. (2019) study which indicated a significant effect of priming watermelon seeds in nanoparticles of biogenic iron, which produced using onion extracts for improving germination and the development of shoots and roots of watermelon seedlings.

3. Germination percentage (GP):

The decrease in the percentage of germination observed at high salinity levels because of the harmful impact of salinity on physiological processes (Khan, et al. 2002). This may also be due to the toxic effects of Na^+ and Cl^- during germination (Khajeh Hosseini et al.2003). Priming seeds with nanofertilizers have significant beneficial effects on germination performance of cucumber seeds under salt stress due to increase solubilization of seed storage proteins (e.g. beta subunit of globulin), reduced lipid peroxidation and increased antioxidant activity in primed seeds. This faster germination was due to DNA, RNA and protein synthesis during priming (Afzal et al.2008). Khodakovskaya et al. (2009) stated that carbon nanotubes increased seed germination and development of tomato plants because of its capacity to penetrate the seed coat and enhance the crucial water uptake.

4. Radicle radius (RR) and radicle surface area (RSA)

In this study, we observed that the highest radicle radius (RR) of cucumber seedling was obtained at highest salt concentration 10 dSm^{-1}, due to salinity effect as a result of increase osmotic potential under salinity conditions. But nanopriming especially 50% nFs priming treatment had the best effect at which a high decrease in RR. Therefore, the soaking in various concentrations of nanofertilizers improved tolerance of cucumber seedlings to salt stress than seeds primed in fresh water and bulkfertilizers. In contrast we observed that the lowest radicle surface area (RSA) of cucumber seedling was obtained at highest salt concentration 10dSm^{-1}, due to the toxic effect of salt stress which led to harmful effect on all growth parameters. The results indicated that, seed priming in 50% nanofertilizers showed a better tolerance and improved RSA at salt stress than ones primed in fresh water and bulkfertilizers. This results in agreement with Yan, M. (2015) study which indicated that priming chinese cabbage seeds in KNO_3 and urea increased germination traits at all levels of drought stress as compared to the unprimed seed. This was due to seed priming treatments led to modulate the antioxidant enzymes activities like peroxidase (POD), superoxide dismutase (SOD) and catalase (CAT) and levels of soluble sugar and proline.

5. Salt tolerance (STI), vigor indices (VI) and radicle Length Ratio (reduction / increase (RLR %))

As expected, STI, VI and RLR % decreased by increasing salinity levels for all priming treatments but priming in NPK nanofertilizers (50%) produced seedlings having a higher tolerance and more vigorous seedling rather than fresh water and bulkfertilizers priming treatments to salinity conditions. The Small size of the nanoparticles would have easily entered through cracks present on the outer seed surface, reacted with free radicals resulting in enhanced seed vigor (Cumbal, et al. 2005). This result agreed with the study by Mahdy et al. (2020) who indicated that nanopriming in water treatment residuals raised STI of cucumber seedlings under salt stress. Tejaswini et al. (2019) study showed that nanopriming of ZnO (500ppm),

TiO_2 (50ppm) and SiO_2 (25ppm) had given the greatest effect on groundnut seedling vigor index and improve germination percentage and root length. Also, the study of Elkhatib et al. (2019) which investigated that nanopriming in mango peels improved the vigor index of maize seeds.

CONCLUSION

Seed priming with NPK nanofertilizers at a rate of 50% of bulkfertilizers demonstrated a successful response against reduction of growth parameters in cucumber seedlings under salinity stress. Through increasing radicle, plumule length, the index of salt tolerance and vigor of cucumber seedlings. Also, priming in nanofertilizers significantly increased the total biomass of cucumber seedlings, radicle surface area in comparison with fresh water and bulk-fertilizers treatments. On the contrary, priming in nanofertilizers treatments significantly decreased the radicle radius. Our results suggested that nutrient seed priming in NPK nanofertilizers solution is a greater promise for agricultural applications, simple, low-cost, and ecofriendly technique which may demonstrate a protective mechanism against oxidative damage and improve cucumber plant tolerance to salt stress, through penetration of nutrients from soaking in nanofertilizers to seed coat ,but future research should be directed towards explaining the physiological and biochemical studies during salinity stress for different crops.

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تعزيز نمو الخيار بالنقع في الأسمدة النانوية تحت ظروف الاجهاد الملحي

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تؤثر الملوحة تأثير ضار على جميع مراحل نمو الخيار وخاصة مرحلة الإنبات ولذلك من المحتمل أن معاملة البذور بالنقع في الأسمدة النانوية يعد نهجًا واعدًا للتعامل مع الآثار الضارة للملوحة على نمو النبات وتطوره. ولذلك تهدف الدراسة الحالية إلى تقييم تأثير نقع بذور الخيار في الأسمدة النانوية المصنعة تحت ظروف الإجهاد الملحي. تم نقع بذور الخيار في الماء المقطر والأسمدة المعدنية (NPK) والأسمدة النانوية (50٪، 25٪، 12.5٪) كنسبة مئوية من الأسمدة المعدنية المستخدمة. تم استخدام خمسة مستويات من الملوحة (0.7، 2.5، 5، 7.5، 10 ديسيسيمنز لكل متر) لري الشتلات لمدة 7 أيام. وقد أوضحت النتائج المتحصل عليها أن زيادة مستويات الملوحة قلل بشكل كبير من طول الجذور والمجموع الخضري، ووزن الشتلات الرطب والجاف، ونسبة الإنبات، ومساحة سطح الجذر، ومقياس تحمل الملوحة%. في حين زاد نصف قطر الجذير مع زيادة مستويات الملوحة. ولكن أدى نقع البذور في الأسمدة النانوية إلى تحسين النسبة المئوية لإنبات البذور وطول الجذور والمجموع الخضري، والأوزان الطازجة والجافة لكليهما، ومساحة سطح الجذر، ومقياس تحمل الملوحة%، مع تقليل نصف قطر الجذير مقارنة بباقي المعاملات.من هذا يتضح أن نقع البذور في الأسمدة النانوية قلل من التأثير الضار للملوحة وكانت تقنية ناجحة في التخفيف من الإجهاد الملحي التي تعرضت لها شتلات الخيار خلال مرحلة الإنبات.

الكلمات المفتاحية: الإنبات ـ الأسمدة النانوية ـ قطر الجذيرـ الأجهاد الملحى ـ مؤشر القوة ـ نقع البذور