Effects of silicon dioxide nanoparticles (SiO_2-NPS) on improving celery seed germination indicators

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Abstract

Nanotechnology has a wide range of applications in many fields, due to the physical properties of small sizes such as the increase in surface area to volume ratio, in the current study, silicon oxide nanoparticles (SiO_2- NP_S) were synthesized by sol gel method. the synthesized SiO_2 nanoparticles were characterized by using XRD, UV-visible spectrophotometry, FTIR and Zetasizer analytical methods. XRD pattern shows the broad peak at (22˚) corresponds to the typical diffraction of amorphous SiO_2- NP_S, UV-visible absorption peak was found at 240 nm. FTIR is certain the presence of Si-O-Si and Si-O vibration peaks, and Zetasizer confirmed that the confirmed that the synthesized silicon oxide nanoparticles are in the size range of 40-80 nm. Six concentrations of SiO_2- NP_S were prepared (5, 20, 40, 60, 80, 100 mg/l). Celery seeds were soaked in these concentrations separately and growth indicators were measured. The concentration of 100 mg/L of SiO_2- NP_S gave the best results in all growth indicators represented by the lengths and weights of the shoots and roots of celery seedlings. it could be concluded with this study the importance of using silicon oxide nanoparticles to improve growth of agricultural crops.

Keywords: SiO_2-Nps, Nanoparticles, germination, seedling growth, Celery.

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1. Introduction

Nanomaterials are defined as materials with dimensions ranging between (1-100) nanometers in at least one dimension, the term nano means small, and it refers to one billionth of a meter (10^{-9}) [1] The physical, chemical and biological properties of nanoparticles differ from those of larger particles of the same material and the changes that occur include several properties such as colour, solubility, strength, electrical conductivity, chemical reaction and biological activity [2]. Nowadays, interest in the manufacture of nanomaterials has increased due to its application in many areas that include medical, industrial and other sectors [3]. as well as its contribution to agricultural practices through improved growth, management and storage of crops [4]. Several nanoparticles have been used in agricultural fields to improve plant growth and development, such as AlO, CuO, FeO, MnO, and ZnO [5]. Silica nanoparticles (SiO_2.NP_s) are one of the most popular nanomaterials that have been used in these fields, due to their characteristics, such as small size, high surface-to-volume ratio, high surface reactivity, ease of fabrication and low production cost [6]. Although silicon (Si) is not usually considered an essential component in plants, studies have shown that its application leads to desirable effects, increasing plant growth indices, increasing yields [7] and improving plant resistance to biotic stresses [8] and abiotic stresses [9] and enhance photosynthesis [10]. These effects have been recognized in several studies involving different plant species [11] showed that the use of SiO_2-NPs significantly improved the germination indices of tomato seeds [12] showed positive effects of SiO_2-NP_s on germination and seedling growth of *Agropyron elongatum*. Foliar spraying of *Carthamus tinctorius* also improved plant growth and plant morphological characteristics, according to [13]. Celery (*Apium gravolens* L.) is one of the most important vegetables in the Apiaceae family. It is grown all over the world and used in the food and cosmetic industries, as it is a great source of vitamins, proteins, phenolic compounds and volatile oils, in addition to its importance in the pharmaceutical industries because of its various medicinal properties, antibacterial, anti-inflammatory and anti-diabetic, so this research aims to synthesize Silica nanoparticles and study its effect on improving germination and vegetative growth of celery plants.

2. Materials and methods:

2.1. Preparation of silicon oxide nanoparticles:

SiO_2-NP_s were prepared by sol-gel method, in which equal amounts of ammonia and ethanol (30) ml each were mixed, and a sodium silicate solution was added to the mixture slowly and dropwise. The mixture was centrifuged to obtain the formed precipitate, washed with distilled water several times and dried to obtain silica nanoparticles [14]. Various techniques have been used to characterize the synthesized SiO_2-NP_s. Silica particle sizes were measured by Zeta sizer. Optical absorption behavior was analyzed using UV-Vis. To study the structure of SiO_2 nanoparticles, an X-ray diffraction (XRD) machine with analytical PAN (CuK = 1.54 nm) was used. The scan value was 2˚ per minute in the range of 10˚ up to 80˚, FTIR in the acquisition range of 400-4000 cm^{-1} used to study the functional groups of SiO_2-NP_s.

2.2. Celery seed germination tests:

Six concentrations of SiO_2-NP_s (5, 20, 40, 60, 80 and 100) mg/L were prepared. Celery seeds after purification were soaked for four hours in six concentrations of SiO_2-NP_s separately, for comparison Sodium silicate was used at the same concentrations, while distilled water was used as a control. (25) seeds were placed in Petri dishes containing filter paper, with three replicates for each concentration. The experiment lasted (12) days and the number of germinated seeds was recorded. The seeds were considered germinated when the root length reached (2) mm [15]. At the end of the experiment the following indicators were recorded: percentage and speed of germination, lengths and fresh weights of the shoot and root.

3. Statistical Analysis:

All data were analyzed by the statistical program spss software (2016). Data were subjected to a completely randomized ANOVA. The mean test of least significant difference (LSD) followed by Duncan's Multiple-Range Test was used at probability level $p < 0.05$.

4. Results:

4.1. characterization of silicon oxide nanoparticles:

XRD pattern shows the broad peak at (22˚) corresponds to the typical diffraction of amorphous SiO_2, this broad XRD reflection peak may be due to the small size of the prepared particles. figure (1). The average size was calculated by using the Debye- Scherrer's equation ($D = K\lambda/\beta \cos\theta$), where D is the size, K stands for Debye Scherrer constant, λ is the wavelength of the utilized X-ray (λ = 1.5406 Å), β is the width of the peak of half maximum, and θ is the Braggs angle. From the previous equation, the average size of synthesized SiO_2-NPs was obtained around 23 nm. this pattern is the same with the XRD of SiO_2 NPs produced by many researchers [16] observed a broad peak at 2θ = 23˚ which can be assigned to the SiO_2-NPs. [17] evaluated The crystallinity of silica nanoparticles from the X-Ray Diffraction pattern. The X-ray diffraction pattern showed a wide range of absorption in the region of about 2θ = 15–25° confirming the amorphous nature of the synthesized the SiO_2-NPs [18]. The peaks at 2θ values of (22) are consistent with the crystalline nature of the silica nanoparticles. [19] showed the hump was widened and a strong peak at (22°-23°). The broad diffraction peak at 2θ = 23° and the absence of any diffraction peak from impurities confirmed the formation of pure amorphous silica nanoparticles as reported by [20].

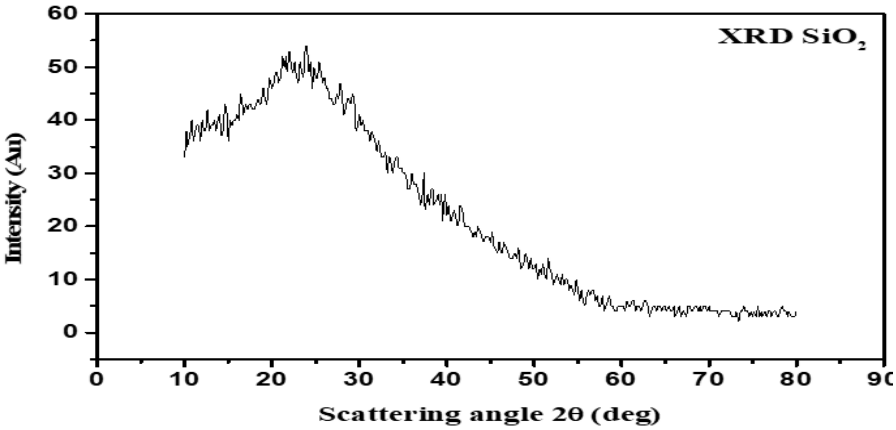

Figure (1): XRD pattern of SiO_2 nanoparticles

The UV-visible absorption spectra of silicon oxide nanoparticles in the 200-900 nm range were recorded. The absorption spectra in Figure (2) shows presence of a single absorption peak in the UV range with maximum absorption band edge of 240 nm. The optical property of silica nanomaterials is related to the occurrence of various defects caused by the partial formation of a Si-O-Si tetrahedral network at the surface, namely silicon and oxygen vacancies [21, 22]. The absorption spectrum is consistent with that of SiO_2 NP_S in several studies [23, 22].

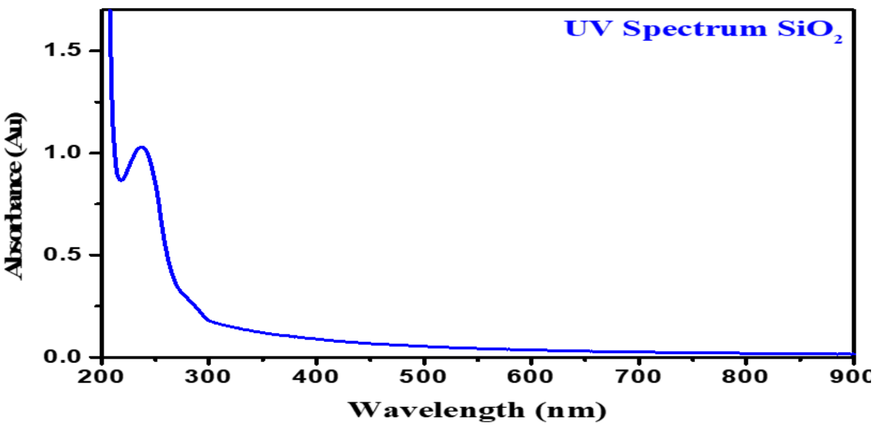

Figure (2): The UV- spectroscopy of SiO_2 nanoparticles

FTIR spectrum (400 – 4000) cm^{-1} confirms the presence of SiO_2-NP_s nanoparticles Figure (3), the characteristic bands approximately at 460, 780 and 1100 cm^{-1} are ascribed to the vibrational modes of SiO_2 which is the out-of-plane, bending, and stretching, respectively. Which is based on the O-Si-O bonding configuration. The position and shape of the main Si-

O vibrational band at 1100 cm^{-1} shows a silicon dioxide stoichiometric structure. In addition, the presence of the broad peak from 3000 to 3500 cm^{-1} indicates an O-H group. The peak at 1640 cm^{-1} refer the presence of an O-H stretching bond. The results we obtained from the FTIR spectrum are consistent with several studies. [24, 25, 26].

Figure (3): FTIR spectra of SiO_2 nanoparticles

The size of the silicon oxide nanoparticles was determined by Zeta Sizer. Figure (4) shows a size distribution ratio, where the size ranged between (40-80) nm., and the average particle diameter was (55) nm.

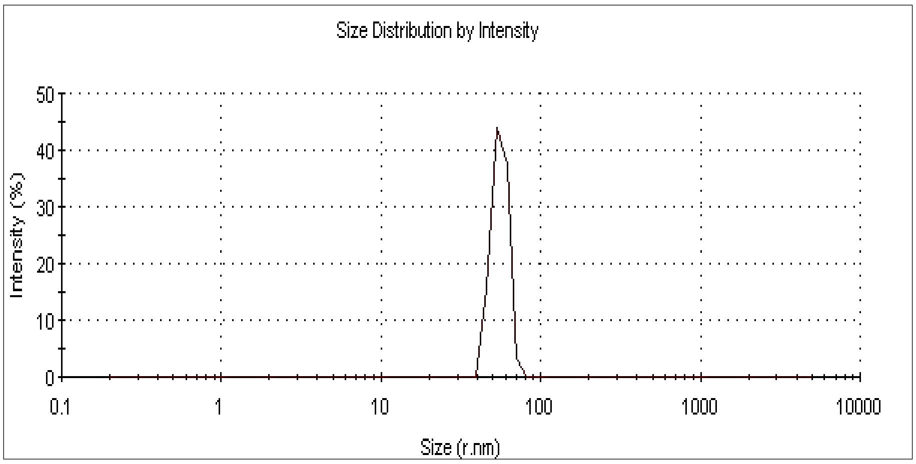

Figure (4): Average particle diameter of silicon oxide nanoparticles

4.2. Effects of SiO_2-NPs on seed germination rate and seedling growth:

The results presented in Figure (5) showed a gradual increase in the seed germination of celery with significant differences when the seeds were treated with SiO_2-NP_s, where the values ranged between (84-74.4%), compared to the control (74.4%). While the values of the treatment with sodium silicate ranged between (80-73.2%), where the concentrations (5,80,100) mg/L recorded a value of (80%).

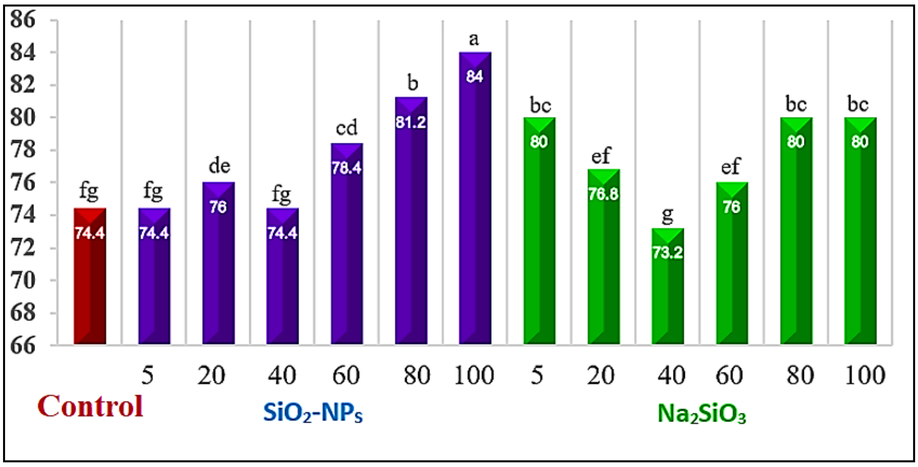

Figure (5): Effect of SiO_2-NPs and Na_2SiO_3 on seed germination rate (%)

The results shown in Figure (6) indicate a significant increase in germination speed when treated with SiO_2-NP_s, where the highest value of (5.3) seeds per day was recorded at concentrations (40) and (80) mg/l, while the speed decreased when using at concentration (100) mg/l to reach (4.3) seeds, The germination speed of seeds treated with sodium silicate ranged between (3.1) and (4.8) seeds/day, and the highest value of germination speed was (4.8) seeds when treated with (60) mg/l, while the control recorded the lowest value (2.7) seeds/day.

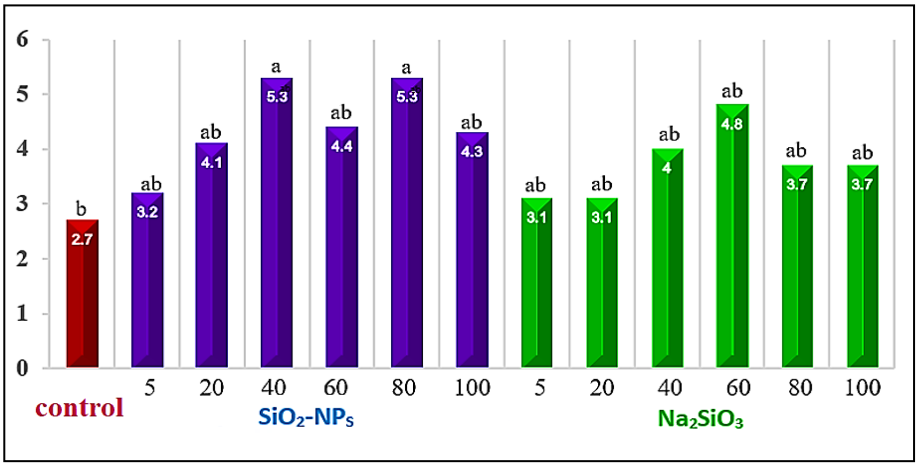

Figure (6): Effect of SiO_2-NPs and Na_2SiO_3 on germination speed (seed/day)

The results clear that the parameters of seed germination rate and speed improved when treated with silicon. The results of the current study are consistent with many studies, [11] explained the role of SiO_2-NPs in promoting the germination of tomato seeds, and the concentration (8) mg/l showed highest values for seed germination. [27] showed that the germination characteristics were significantly improved for *Oryza sativa* seeds treated with sodium silicate and SiO_2-NPs compared to untreated seeds. according to [28] The rate of corn germination improved when treated with silicon and the effect of SiO_2-NPs was more clear compared to seeds treated with sodium silicate according to [28]. [29] also showed that the germination rate of *V. faba* L. seeds increased by (47.7%) compared to the control when using SiO_2-NPs at a concentration of (2) mmol. In general, the results of previous studies confirm an improvement in the germination rate of seeds when treated with silicon, this can be explained by the small size of nanoparticles enables to penetrate the seed coat more easily than bulk materials of larger sizes, causing many biochemical changes that affect the germination process positively [30]. The silicon oxide nanoparticles can also activate several biochemical reactions that inhibit the production of abscisic acid while increasing the production of gibberellins, which helps break seed dormancy and thus improve seed germination [31].

4.3. Effects of SiO_2-NP_s on shoot and root lengths of celery seedlings

The shoot lengths of celery seedlings increased with the increase in the concentration of SiO_2-NP_S, the highest values were recorded (16) and (15) mm at the concentrations (100) and (80) mg/l, respectively. The maximum length of the shoot reached (13) mm when treated with sodium silicate at the concentrations (60) and (80) mg/l, the length of the control seedlings was (10) mm. As shown in Figure (7)

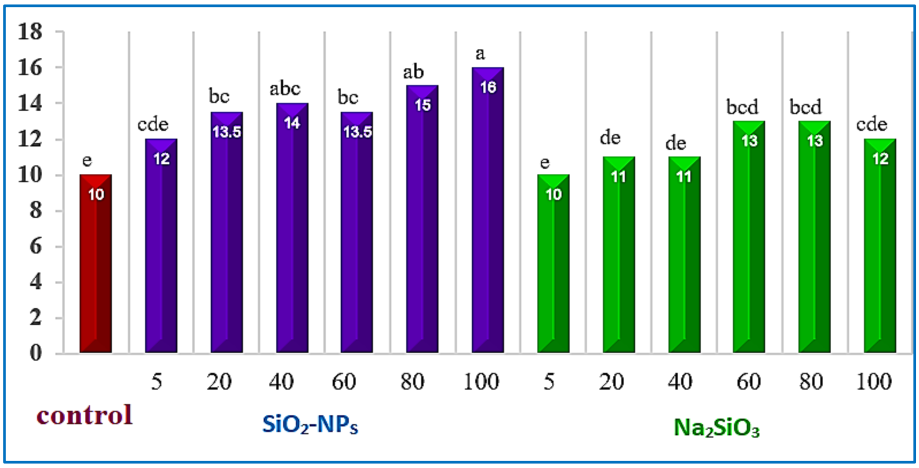

Figure (7): Effect of SiO_2-NPs and Na_2SiO_3 on shoot lengths (mm)

As for the root length, the concentration (100) mg/l of SiO_2-NP_S showed the best result (29 mm), followed by the concentration (80) mg/l, (26.5) mm. The values when treated with sodium silicate ranged between (19-26) mm., the control treatment was (18.5) mm. Figure (8).

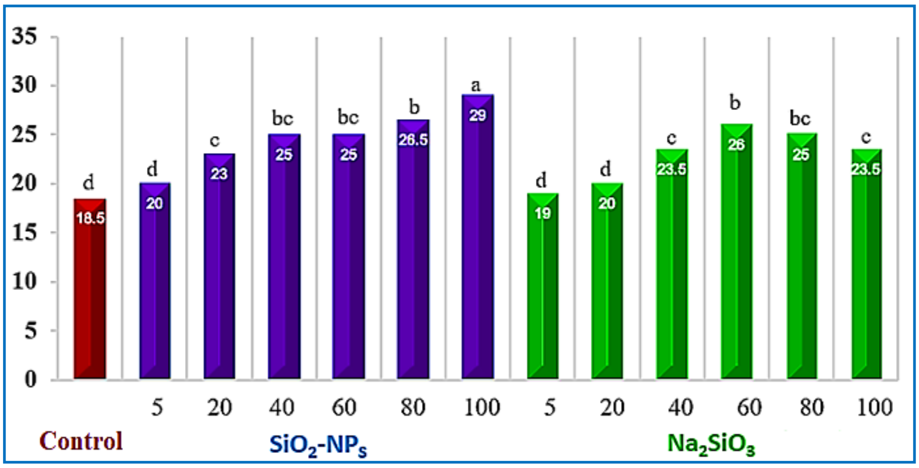

Figure (8): Effect of SiO_2-NPs and Na_2SiO_3 on root lengths (mm)

The results show that celery treated with SiO_2-NP_S gave the highest values, both in shoot and root length, and increased significantly with the increase in the concentration used. This may be due to the role of silicon in activating the metabolic processes, which makes the plant highly efficient in responding to external stimuli [32]. When comparing the same concentrations of silicon oxide nanoparticles and sodium silicate, nanoparticles showed greater effectiveness in increasing seedling lengths, as nanoparticles directly penetrate into plants and improve morphological and physiological indicators of plants, which leads to improved productivity and yield of plants [33]. [18] showed that the use of SiO_2-NP_S led to an increase in the shoot and root lengths of the *Oryza sativa*. The root length of wheat and lupine plants increased when the seeds of both plants were treated with a concentration of (500) mg/l of SiO_2-NP_S [34]. Soaking the seeds of *V. faba* with different concentrations of SiO_2-NP_S and sodium silicate improved plant growth indices [33]. The seedling lengths of *Phyllostachys edulis* increased when the seeds were treated with concentrations (1) and (2) mmol of SiO_2-NP_S [35]. These positive effects of silicon treatment can be attributed to its ability to improve the efficiency of the plant in absorbing water and improving the efficiency of photosynthesis [36]. 1745

4.4. Effects of SiO_2-NP_s on shoot and root weights of celery seedlings

The fresh weights of the shoots ranged between 41 to 30 mg at concentrations 100 to 5 mg/l of SiO_2-NP_S, respectively, compared to the control (28) mg (Figure 9), while the concentration (80) mg/l. gave the best value when treated with sodium silicate (39) mg.

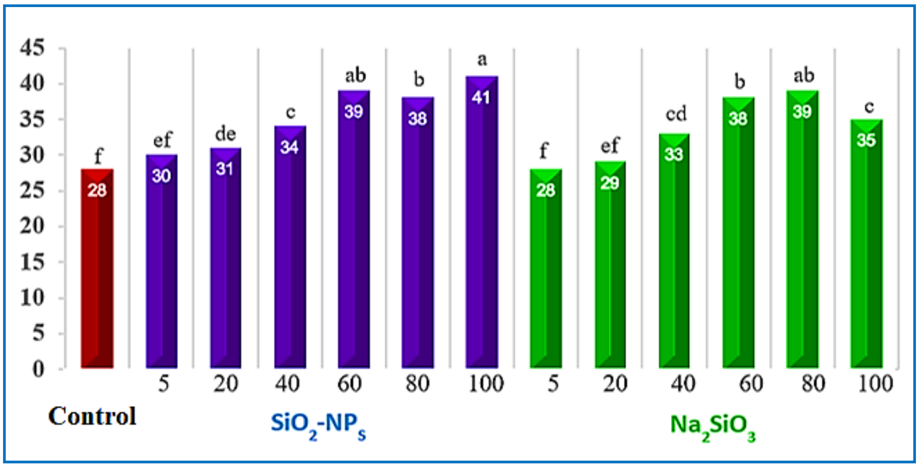

Figure (9): Effect of SiO_2-NPs and Na_2SiO_3 on shoot weights (mg)

The root fresh weights showed a significant increase in the values when applying nano-silicone oxide, reaching the highest value of (85) mg at concentrations (100) and (80) mg/l compared with the control (56) mg. While sodium silicate recorded the highest value (79) g at concentration (100) mg/l. figure (10)

The increase in shoot and root fresh weights when treated with silicon can explain that silicon increases the efficiency of water use, improves the ability of seedlings to absorb water, and increases the relative water content [37] The results of this study are consistent with [38] which showed a similar effect on the germination of maize seeds when treated with of SiO_2-NP_S. [29] showed that the rate of seed germination and fresh weights of *Vicia faba* were significantly improved when SiO_2-NP_S were used, [11] showed that tomato seeds treated with of SiO_2-NP_S with a size of (12) nm and with different concentrations led to an increase in the fresh and dry weights of seedlings. There was also a significant increase in the fresh weight of wheat and lupine plants by (31.9%) and (25.8%), respectively, when treated with of SiO_2-NP_S at a concentration of (1000) mg/l according to [34].

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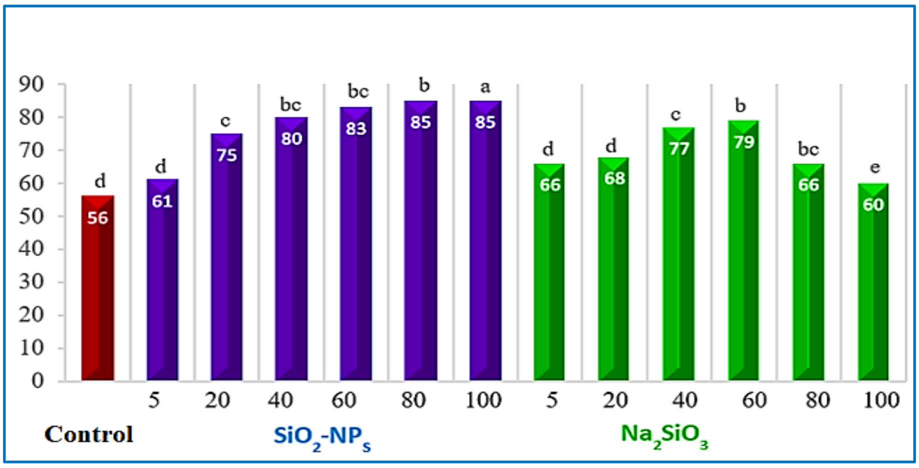

Figure (10): Effect of SiO_2-NPs and Na_2SiO_3 on root weights (mg)

5. Conclusion:

The current study showed the effect of silicon nanoparticles on celery plant germination indicators The graded concentrations affected the different indicators of germination, which increased by increasing the applied concentration of SiO_2-NP_S, and the concentration of 100 mg/l gave the best results in terms of shoot and root lengths and wet and dry weights. This is attributed to the ability of silicon to improve the ability of seedlings to absorb water and thus increase germination processes. Therefore, SiO_2-NP_S play an important role in breaking the dormancy of seeds and increasing growth indicators, which indicates the importance of applying nanoparticle processing technology in the field of agriculture to increase productivity, both quantitatively and qualitatively.

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