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The effect of perlite particle size and deficiency of some essential nutrients on growth and physiological characteristics of radish

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Growing media
Mineral elements
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ABSTRACT

This experiment aimed to investigate the impact of macro and micronutrient deficiencies as well as different sizes of perlite particles on radish growth and physiology. A factorial experiment was conducted using a completely randomized design with three replications. The factors tested included deficiency of nutrient elements (control, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, boron, and zinc), and the growing media consisted of small, medium, and large perlite particle sizes. The results of the experiment revealed that the dry and fresh mass of the taproot, root, and shoot, as well as leaf area and the number of leaves, decreased under conditions of nutrient deficiencies. Among the macronutrients, nitrogen deficiency had the most significant impact on reducing vegetative traits. Additionally, the results indicated that nitrogen and boron deficiencies led to the highest and lowest increases, respectively, in the amount of total soluble sugars in the leaves. Furthermore, chlorophyll content and chlorophyll fluorescence indices were most affected by nitrogen deficiency, while boron deficiency had the least impact on these parameters. The study also found that the amount of vitamin C in the taproot decreased when nitrogen, potassium, phosphorus, magnesium, calcium, and iron were deficient. Moreover, perlite particle size had a significant effect on growth indices, mineral element concentration, and photosynthetic pigments. Specifically, using larger perlite particles resulted in a significant decrease in these indices. Based on the findings of this study, it can be concluded that using small-sized perlite in the substrate is better for nutrient absorption and thus promotes the proper growth of radish.

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1. Introduction

The existence of some problems in soil cultivation, such as excess of salinity and inappropriate soil texture and limitation of water resources have led to the development of soilless cultivation. The cultivation of plants without using soil as a rooting medium is known as soilless farming (Gonnella and Renna, 2021). Soilless agricultural production is a highly promising technique for increasing the cultivation of numerous cash crops and for growing plants without the need of soil as a rooting medium (Tzortzakis *et al.,* 2020). Perlite medium is widely preferred as it encourages faster root development, reduces risk of damping off, avoids water logging and provides an optimum balance of air and water. Growth and yield of different crops depends significantly on the sizes of perlite. For example, water holding capacity greatly depends on this characteristic. Ultrafine perlite has smaller pores spaces that hold water strongly, in turns larger particle size perlites has less moisture retention capacity. Therefore, selection of the suitable particle size of perlite is important for maximizing root yield (Asaduzzaman *et al.,* 2013). Use of suitable soilless media can increase both marketable yield and quality of root crops by many folds (Hara, 2009). It is found that the growth, yield and quality of carrot were influenced greatly by the size of the perlite particle. It also was verified greater growth and yield variables of carrots grown in smaller perlite than those grown in bigger perlite. (Asaduzzaman *et al.*, 2013). The provision of information concerning plant nutrition bases, such as identifying nutritional deficiencies, will assist farmers facing decisions on planning future fertilizations (Carmona *et al.*, 2015). Therefore, the assessment of plants nutritional status becomes a valuable tool to try to predict plant's growth, development, productivity and quality by identifying the limiting element (Epstein and Bloom, 2006. The deficiency of N initially causes uniform chlorosis in the cucumber leaf blade of intermediary leaves, and the omission of P, symptoms begin with the loss of the characteristic green color of cucumber plants in the blade of intermediary leaves (Carmona *et al.,* 2015). Deficiency of Ca, Fe, and B in lettuce affected new growth and for Fe was eventually also apparent on recently mature leaves. Sulfur deficiency led to uniform chlorosis along leaves, first evident on new growth and eventually affecting the entire plant (Mattson and Merrill, 2015).

Therefore, finding the suitable perlite size along with optimal concentration of culture solution is a great advantage for maximizing radish yield in hydroponics. Thus, the objectives of this study were to select the most suitable perlite particle size and to grow radish in nutrient solutions deficient of individual macro and micronutrients by evaluating their effects on growth and physiological characteristics of radish grown hydroponically.

2. Materials and Methods

This experiment was conducted in 2020 at the experimental greenhouse of Vali-e-Asr University of Rafsanjan. This experiment aims to compare the effect of deficiency of macro and micro nutrients and perlite particles size on radish, therefore, a factorial experiment was conducted in a completely randomized design with three replications. Factors include deficiency of nutrient elements (control, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, boron, and zinc) and perlite particles size (small, medium and large). Seeds of radish (*Raphanus sativus* L. var. sativus) were purchased from Pakan Bazr Isfahan Company (Isfahan, Iran) and were sown in a plug tray containing cocopeat and perlite. Irrigation of plants was done twice a day. Each time irrigation 150 ml of the nutrient solution was given to the plants. The plants were irrigated with Hoagland nutrient solution (Hoagland and Arnon, 1950). At the end, the plants were treated twice a day for one month with 150 ml of modified Hoagland nutrient solution based on the lack of essential nutrients (Table 1).

Table 1 Nutrient formulations and rates used to induce mineral nutrient deficiencies in radish

Nutrient formulation	Stock solution (mg/l)	Treatment (ml/L nutrient solution)									
		Control	-N	-P	-K	-Ca	-Mg	-S	-Fe	-Zn	-B
$Ca(NO_3)_2.4H_2O$	236.2	5	-	5	5	-	4	4	5	5	5
KNO_3	101.1	5	-	5	-	5	6	4	5	5	5
KH_2PO_4	136.1	1	-	-	-	1	1	1	1	1	1
$MgSO_4.7H_2O$	246.5	2	2	2	-	-	-	-	2	2	2
Micronutrient		1	1	1	1	1	1	1	1	1*	1*
Fe-DTPA	10	1	1	1	1	1	1	1	-	1	1
K_2SO_4	87.15	-	6	1	-	-	-	-	-	-	-
$CaSO_4.2H_2O$	1.722	-	100	-	-	-	200	-	-	-	-
$Ca(H_2PO_4).2H_2O$	12.605	-	20	-	20	-	-	-	-	-	-
$Mg(NO_3)_2.6H_2O$	256.4	-	-	-	2	2	-	2	-	-	-
$(NH_4)_2SO_4$	132.1	-	-	-	-	2	-	-	-	-	-

Minus sign (-) indicated that reagent not applied.

*Omitted Zn and B in micronutrient solution.

2.1. Vegetative growth

In this study, different morphological traits (root length, number of leaves, Leaf area), growth parameters (dry and fresh mass of the taproot, dry and fresh mass of the root, dry and fresh mass of shoot) were measured. To measure dry mass, the samples were placed in an oven at 72 °C for 48 h, and then the dry mass of the samples was recorded. To measure leaf area, three plants were randomly collected from each treatment, and leaf area was measured using a leaf area meter (CI-202, Avenue Camas, USA).

2.2. Pigments Measurements

Pora method was used to measure chlorophyll a, chlorophyll b, total chlorophyll content (Porra *et al.*, 1989), and the Lichtenthaler and Wellburn (1983) method were used to measure the leaf carotenoids concentration.

2.3. Chlorophyll fluorescence

The second leaves from the top were used for the measurement of chlorophyll fluorescence using a Plant Efficiency Analyzer (PEA), Handy PEA (Hansatech Instruments Ltd., Norfolk, UK). Leaves were maintained in darkness for 15 min before taking the data on chlorophyll fluorescence. Maximal quantum yield of PS II photochemistry (F_v/F_m) and performance index (PI) were calculated using the software supplied by the manufacturer.

2.4. SPAD values

The chlorophyll index in young leaves was recorded with a SPAD-502 Chlorophyll Meter (Minolta Camera Co. Ltd., Tokyo, Japan). Three leaves were selected from each pot and measurements were made.

2.5. Soluble carbohydrates

Soluble carbohydrates content was measured by the method of Irigoyen *et al.*, 1992. A total of 0.1 g fresh samples from the mature leaves of radish were ground and extracted with ethanol and subsequently filtered. 0.1 ml of alcoholic extract is prepared with 3 ml of intron (150 mg of intron plus 100 ml 72% sulfuric acid). This solution is placed in a hot water bath for 10 minutes until the reaction is done and colored. Then, the absorbance rate was calculated at a wavelength of 625 nm, and the amount of soluble sugar and its absorption was calculated based on the standard curve obtained from pure glucose in different concentrations.

2.6. Vitamin C

Vitamin C content of radish taproots were carried out by iodine titration. To determine vitamin C, 3 mL of radish taproot juice were diluted and titrated with 20 mL distilled water and 2 mL iodine reagent (2% iodine) in potassium iodide. The titration was continued until the solution changed to gray. One mL iodine regent in potassium iodide equals to 0.88 mg vitamin C (Jacobs, 1959).

3. Data Analysis

Data analysis of variance (ANOVA) was performed using IBM SAS 9.1 software, and the differences between means were assessed using LSD tests at $p\leq 0.05$. The graphs were drawn using Microsoft Excel.

4. Results

4.1. Shoot fresh and dry mass

The results of mean comparison showed that the nutrients shortage decreased shoot fresh mass compared to the control. The highest (% 80) and lowest (%10) fresh mass reduction was observed under nitrogen and boron deficiency, respectively. The results also indicated that the plants that were grown in the small perlite bed had more shoot fresh mass than the plants that were grown in the medium and large perlite bed, and the effect of nutrient deficiency on the shoot fresh mass, was more in the plants that grew in medium and large bed. The results showed that iron deficiency had the greatest effect on the shoot fresh mass compared to the zinc and boron deficiency (Figure 1). The lack of nutrients decreased shoot dry mass. The shoot dry mass was also about 25% and 49% higher in plants grew in small perlite compared to the plants grew in medium and large perlite (Figure 2).

4.2. Root fresh and dry mass

The results of the mean comparison showed that the lack of nutrients decreased root fresh mass compared to the control treatment, and the type of growing medium influenced the effect of nutrient deficiency on root mass. Under the lack of nutrients conditions, the plants that grew in the small substrate had more root fresh mass than the plants that grew in the large and medium perlite substrate. The highest root fresh mass was observed in the control treatment and small substrate, and the lowest root fresh mass was observed in the sulfur deficiency treatment and large substrate (Figure 3). According to the results, the root dry mass decreased under nutrient deficiency conditions. Under the lack of nutrients conditions, the plants grew in the large perlite substrate had lower root dry mass than the plants grew in the small substrate (figure 4). The highest and lowest root dry mass were observed in the control plants that were grown in the small perlite substrate, and plants that were grown under nitrogen deficiency and large perlite conditions respectively. The results also showed that the lack of micronutrient elements significantly decreased the root dry mass. Among the micronutrients boron had a greater effect on the reduction of root dry mass (Figure 4).

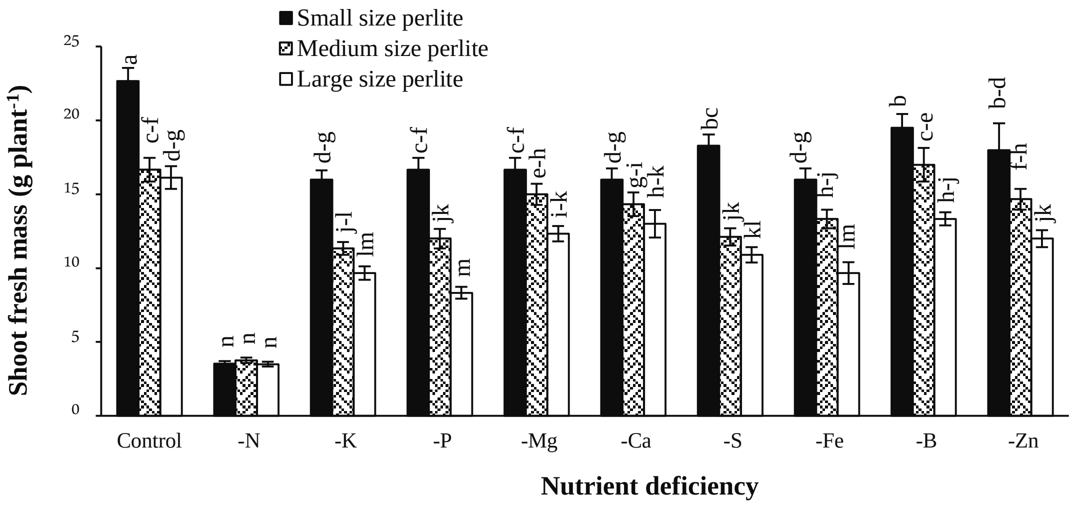

Figure 1 The effect of perlite particle size and deficiency of some essential nutrients on shoot fresh mass of radish.

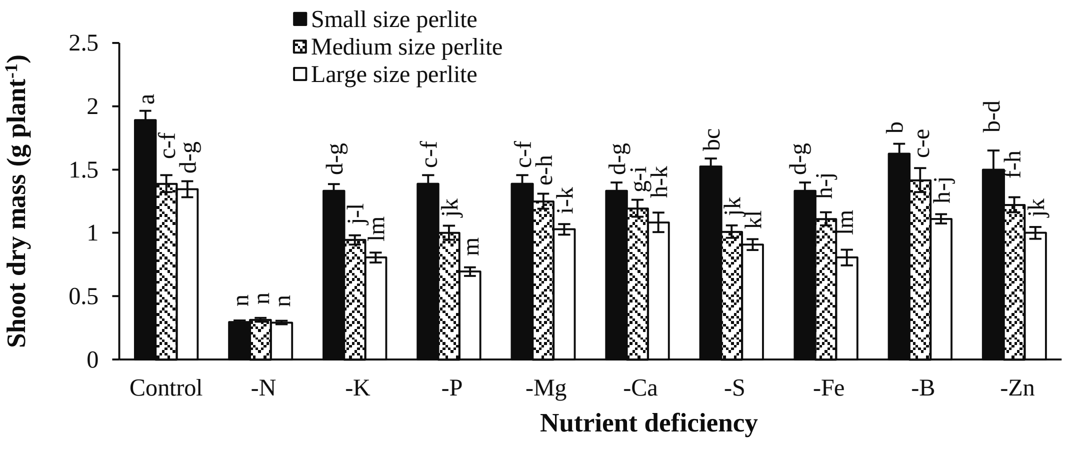

Figure 2 The effect of perlite particle size and deficiency of some essential nutrients on shoot dry mass of radish.

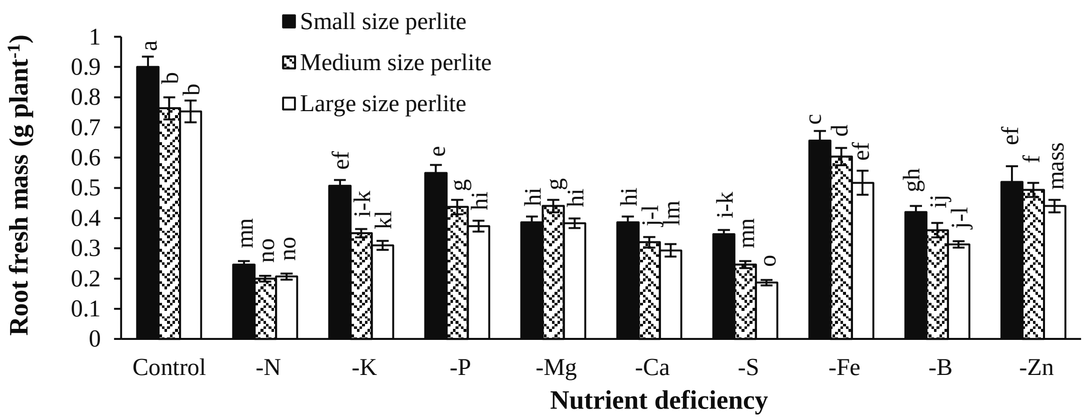

Figure 3 The effect of perlite particle size and deficiency of some essential nutrients on root fresh mass of radish.

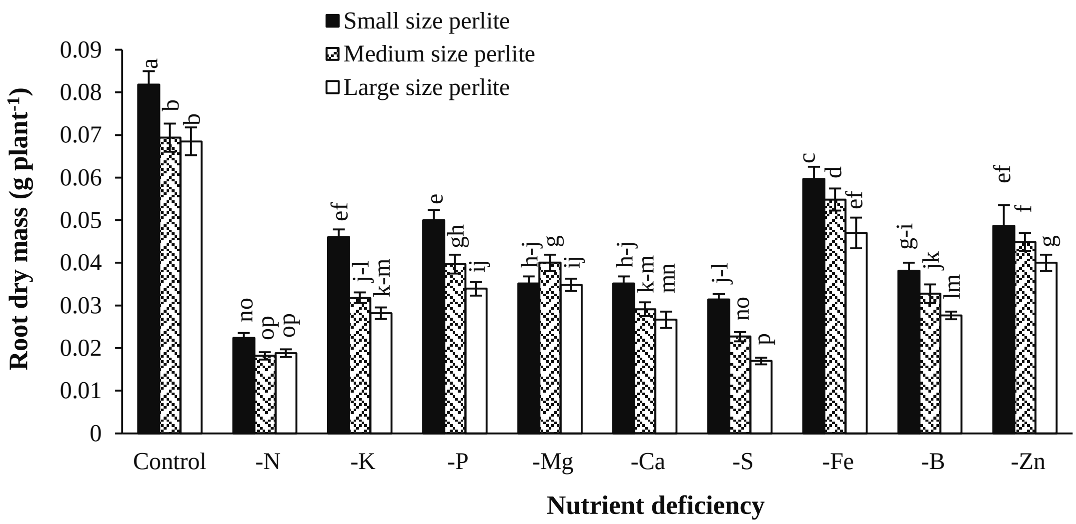

Figure 4 The effect of Perlite particle size and deficiency of some essential nutrients on root dry mass of radish.

4.3. Number of leaves

Results showed that the lack of nutrients decreased number of leaves compared to the control. The highest (33%) and lowest (9%) reduction of leaves number was observed under nitrogen and boron deficiency, respectively. The effect of nutrient deficiency on the number of leaves was greater in plants that grew in medium and large substrate (Figure 5).

4.4. Leaf area

Figure 6 showed, nutrients shortage decreased leaf area. The leaf area in plants grew in small perlite substrate was 13% and 18% higher than plants grew in medium- and large perlite, respectively.

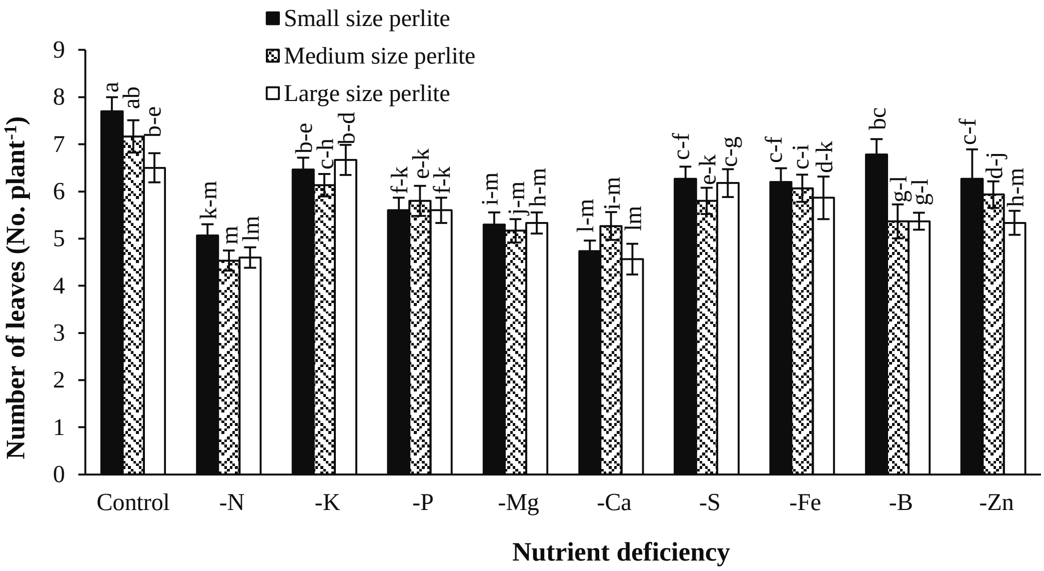

Figure 5 The effect of perlite particle size and deficiency of some essential nutrients on number of leaves of radish.

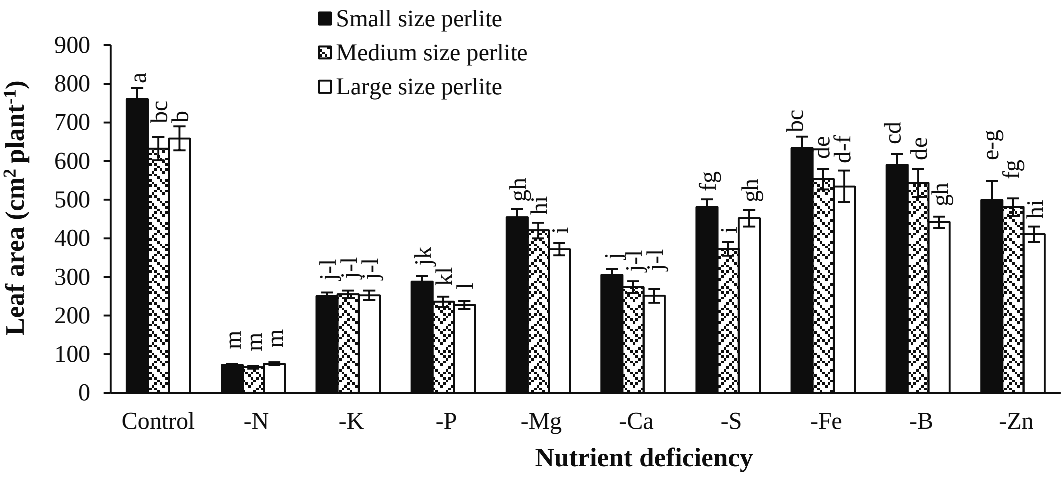

Figure 6 The effect of perlite particle size and deficiency of some essential nutrients on leaf area of radish.

4.5. Root length

The results showed that the root length decreased significantly under nutrient deficiency compared to the control. Root length was more reduced under nitrogen deficiency (Figure 7).

4.6. Taproot fresh and dry mass

Nutrients shortage decreased dry and fresh mass of the taproot. The taproot fresh mass in plants grew in small perlite substrate was 12% and 28% higher than plants grew in medium and large perlite, respectively (Figure 8). According to the results, the taproot dry mass decreased under nutrient deficiency conditions, and the plants grew in the large perlite substrate had lower taproot dry mass than the plants grew in the small substrate. The highest and lowest taproot dry mass were observed in the control plants that were grown in the large perlite substrate, and plants that were grown under nitrogen deficiency and large perlite conditions, respectively (figure 9).

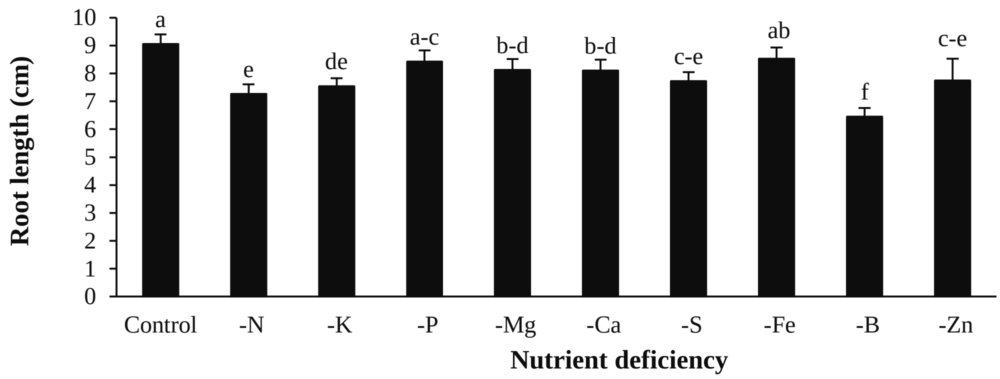

Figure 7 The effect of deficiency of some essential nutrients on root length of radish.

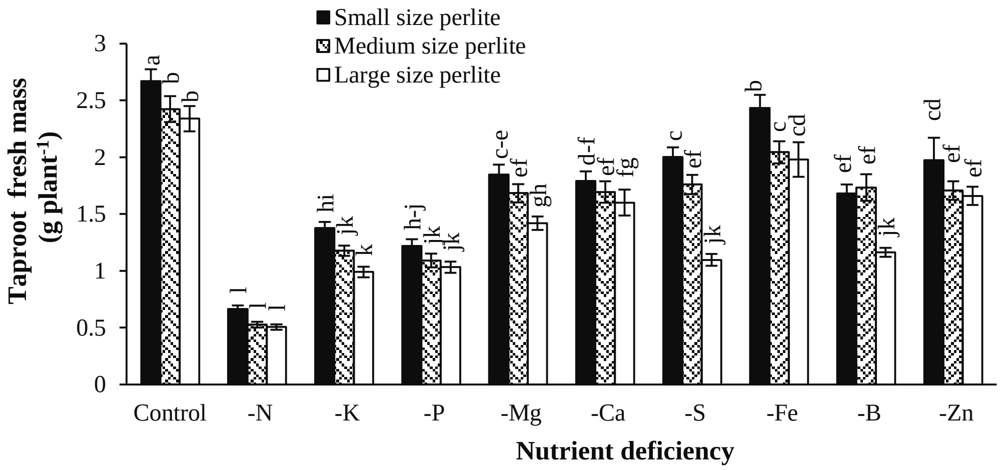

Figure 8 The effect of perlite particle size and deficiency of some essential nutrients on Taproot fresh mass of radish.

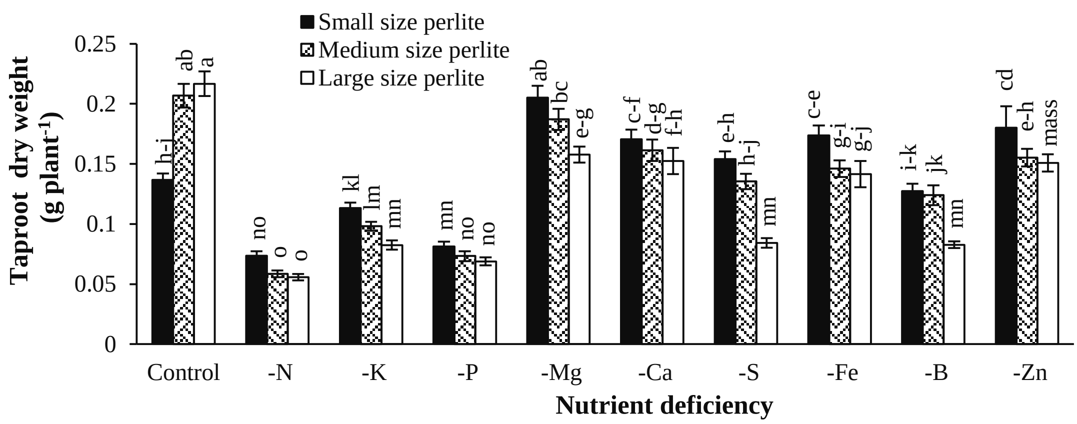

Figure 9 The effect of perlite particle size and deficiency of some essential nutrients on Taproot dry mass of radish.

4.7. Photosynthetic pigments

The results of the mean comparison showed that the lack of nutrients decreased photosynthetic pigments compared to the control treatment. Chlorophyll content had the highest and lowest decrease under nitrogen and boron deficiency conditions, respectively. The results also showed that perlite particles size had a significant effect on the value of chlorophyll and carotenoids content. The total chlorophyll content was also higher in plants grown in small perlite compared to the plants grown in medium and large perlite (Figure 10 to 14).

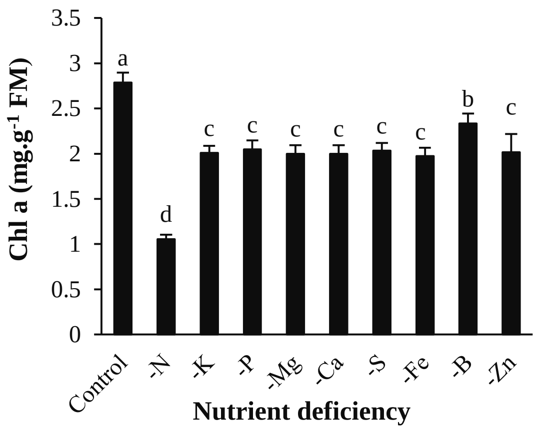

Figure 10 The effect of deficiency of some essential nutrients on chlorophyll a content of radish.

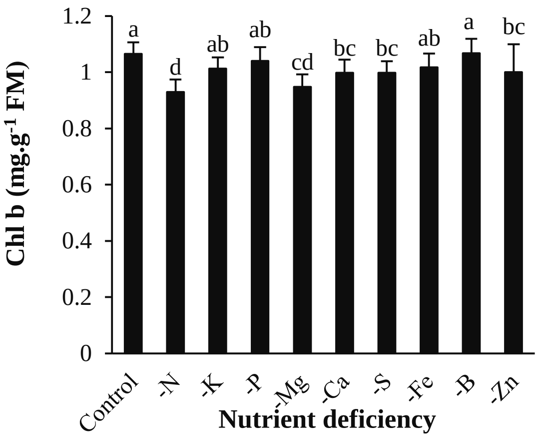

Figure 11 The effect of deficiency of some essential nutrients on chlorophyll b content of radish.

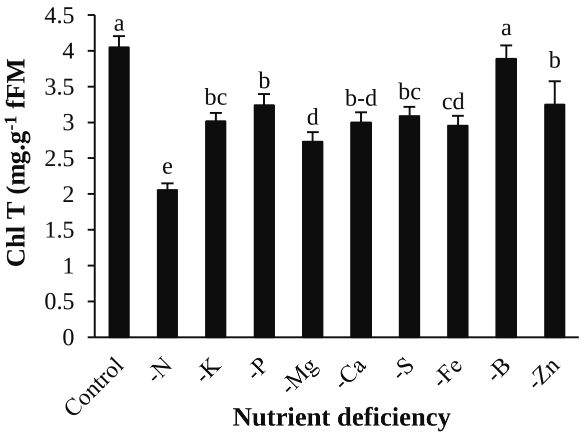

Figure 12 The effect of deficiency of some essential nutrients on total chlorophylls content of radish.

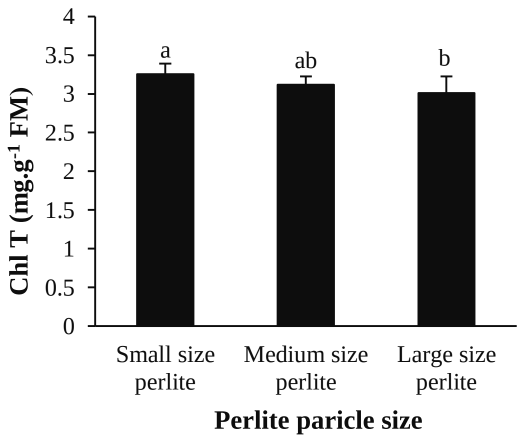

Figure 13 The effect of perlite particle size on total chlorophylls content of radish.

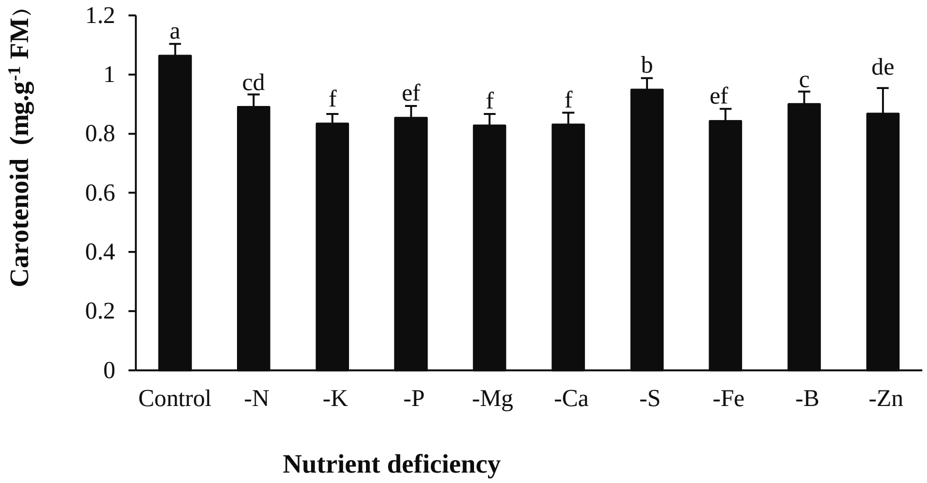

Figure 14 The effect of deficiency of some essential nutrients on carotenoid content of radish.

4.8. Chlorophyll fluorescence

Results showed that the lack of nutrients decreased F_v/F_m and PI indices compared to the control. The highest (12.5%) and lowest (2.2%) reduction of F_v/F_m was observed under nitrogen and boron deficiency, respectively. The effect of nutrient deficiency on the F_v/F_m and PI indices was greater in plants that grew in medium and large substrate (Figure 15, 16).

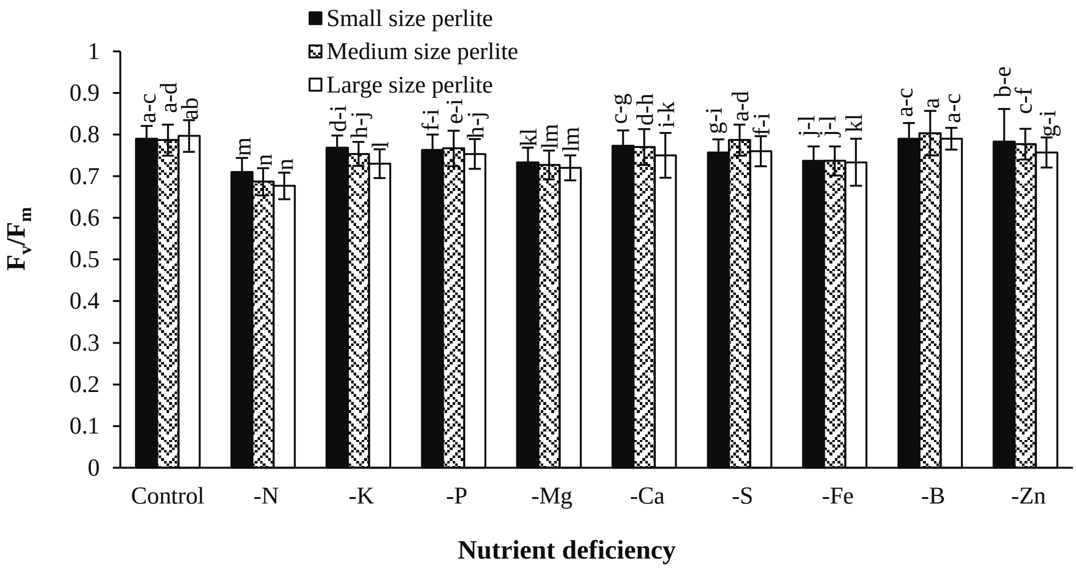

Figure 15 The effect of perlite particle size and deficiency of some essential nutrients on maximum quantum yield of PS II photochemistry (F_v/F_m) of radish.

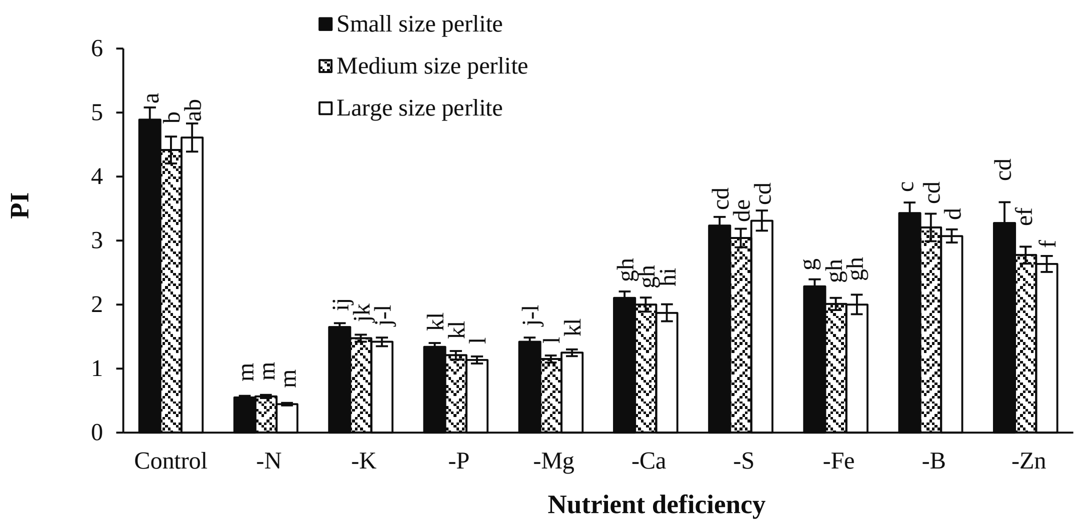

Figure 16 The effect of perlite particle size and deficiency of some essential nutrients on PI indices of radish.

4.9. SPAD values

Results showed that the deficiency of nitrogen, sulfur, iron and boron caused a decrease of 32, 14, 18 and 9% in SPAD values compared to the control, respectively (Figure 17).

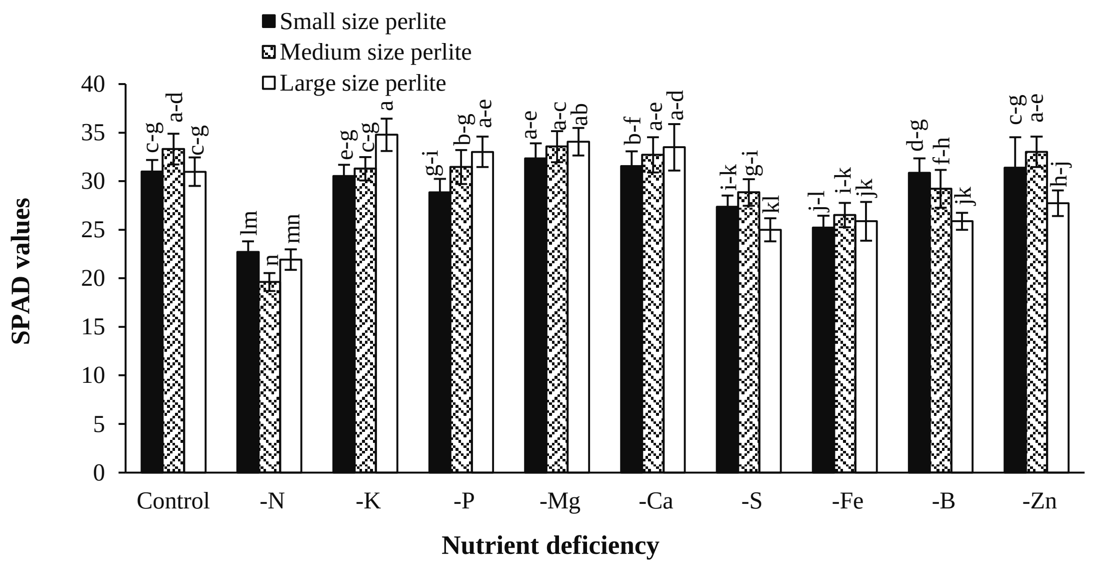

Figure 17 The effect of perlite particle size and deficiency of some essential nutrients on SPAD values of radish leaves.

4.10. Vitamin C

The amount of vitamin C in the radish taproot also decreased under conditions of nitrogen, potassium, phosphorus, magnesium, calcium and iron deficiency. However, in the conditions of boron and zinc deficiency in plants, there was no significant difference in the amounts of vitamin C in the taproot (figure 18).

4.11. Total soluble sugars

Results showed that the lack of nutrients increase the total content of soluble sugars of leaves compared to the control. The total content of soluble sugars of leaves in nitrogen and boron deficiency respectively had the highest and lowest increase (figure 19). The content of total soluble sugars of taproot in calcium and boron deficiency respectively had the highest and lowest decrease (figure 20).

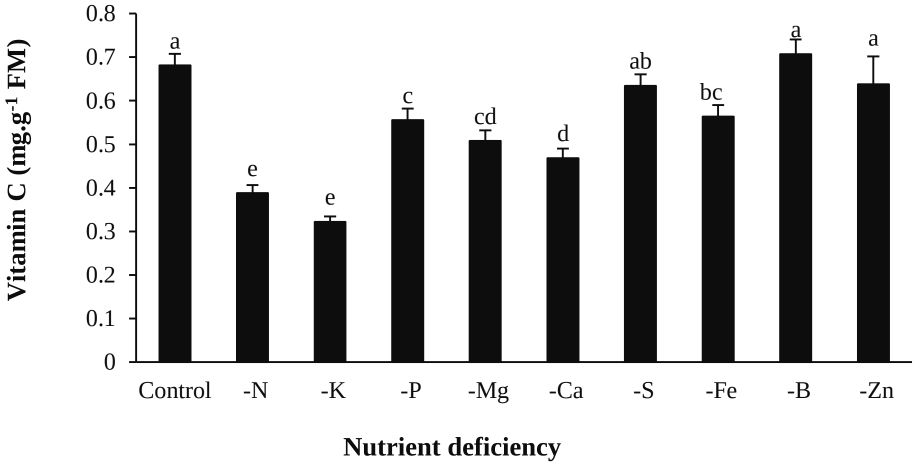

Figure 18 The effect of deficiency of some essential nutrients on vitamin C of radish taproot.

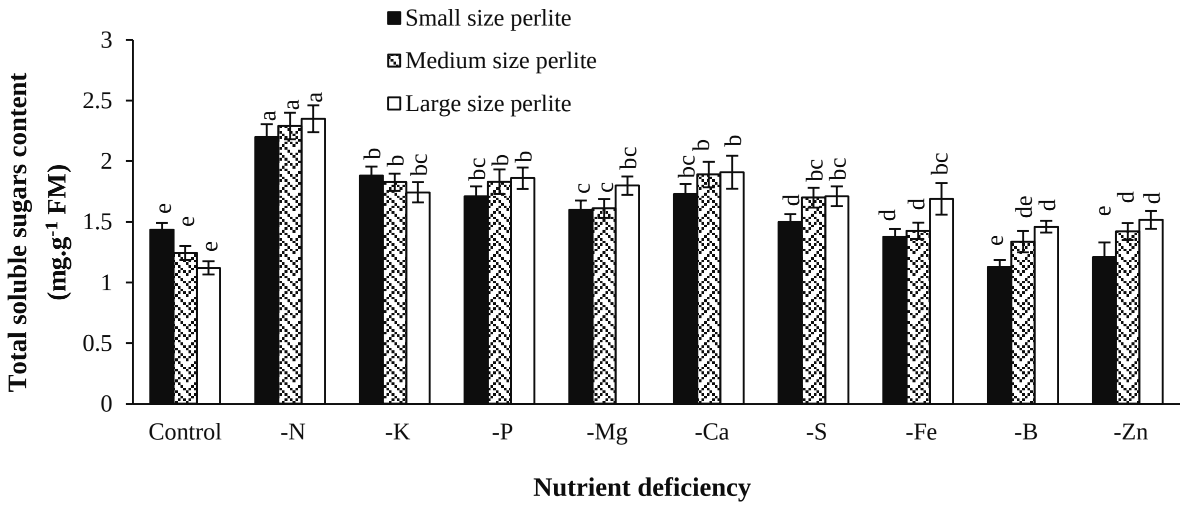

Figure 19 The effect of perlite particle size and deficiency of some essential nutrients on leaf soluble sugars content of radish.

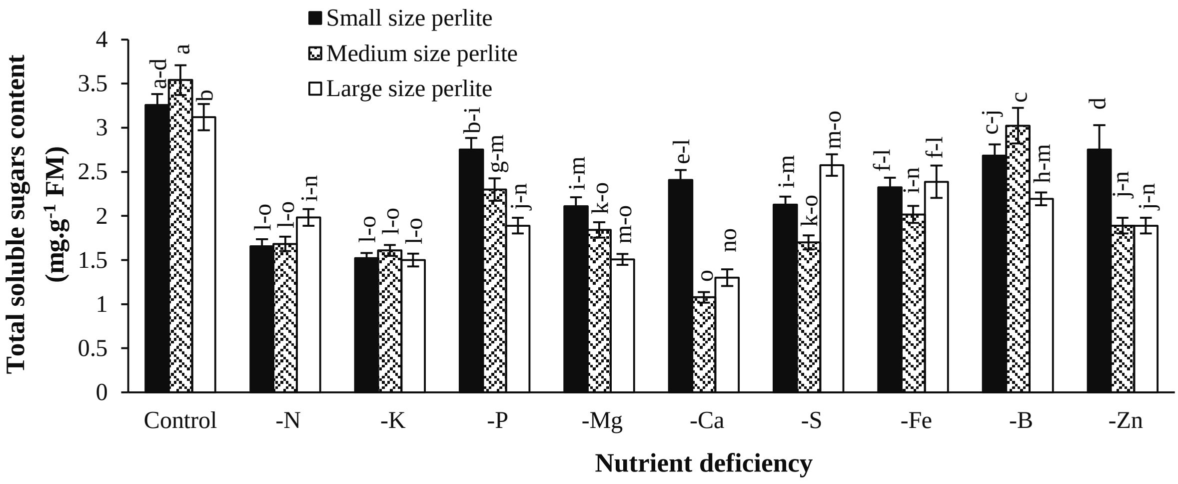

Figure 20 The effect of perlite particle size and deficiency of some essential nutrients on taproot soluble sugars content of radish.

5. Discussion

5.1. Plant growth

The results of the present research showed that nutrient deficiencies significantly decreased growth traits of radish. Since nitrogen is among the most important nutrients required by plants, its deficiency is one of the key factors limiting their growth. It has been reported that nitrogen deficiency leads to chlorosis of the lower leaves and decreases dry matter production in radish (Roosta, 2017). It has been reported that nitrogen deficiency has negative effects on growth traits of lettuce (Broadley *et al.*, 2000), tomato (Frias-Moreno *et al.*, 2014), cabbage (Kano *et al.*, 2007), and sweet potato (Wei *et al.*, 2015). Nitrogen plays a role in many physiological and biochemical processes in plants. Hence, its deficiency reduces plant growth. Research has shown that nitrogen deficiency results in degradation of chloroplast membranes thereby reducing photosynthetic rate and dry matter production (Cetner *et al.*, 2017). In agreement with the results of the present research, other studies have reported that phosphorus deficiency reduces growth of tomato (Li *et al.*, 2010) and radish plants (Sanchez *et al.*, 1991). Phosphorus deficiency leads to accumulation of sugar and starch in plant tissues. In general, phosphorus deficiency reduces rubisco activity, which leads to accumulation of ribulose-1, 5-bisphosphate and completely stops photosynthetic activity (Hermans *et al.*, 2006). Potassium is involved in protein synthesis, anion-cation balance, the opening and closing of plant stomata, osmoregulation, and photosynthesis (Marschner, 2011). Potassium deficiency decreases photosynthesis and translocation of photoassimilates in the phloem, which cause oxidative stress in plant tissues and, eventually, reduce its growth (Hafsi *et al.,* 2014). Petrazzini *et al* (2014) showed that decreased potassium content negatively influenced lettuce growth traits by disrupting the anion-cation balance. Magnesium ion is present in chlorophyll, and its deficiency changes the content and structure of photosynthetic pigments in leaves thereby decreasing photosynthetic rate (Marschner, 2011). In agreement with the results of the present research, it has been reported by other researchers that magnesium deficiency reduces growth rates of sunflower (Farhat *et al.*, 2016) and pepper (Riga and Anza, 2003) plants. Calcium acts as a messenger and its deficiency changes expression levels of many genes that encode enzymes (Cheval *et al*., 2013). Sulfur is also present in the amino acids cysteine and methionine and plays a fundamental role in plants (Cheval *et al*., 2013). Therefore, considering the roles played by these two elements in plants, their deficiencies also decrease plant growth. In agreement with the results of this study, other researchers have shown that sulfur deficiency negatively affects growth traits of chinese cabbage (Reich *et al.,* 2016). Micronutrients play complicated roles in plant nutrition and crop production (Ronen, 2016). Iron is involved in photosynthesis and formation of chlorophyll molecules. The typical symptom caused by iron deficiency is yellowing leaves with green veins (Benton Jones, 2005). The results of the present research showed that iron, boron, and zinc deficiencies had significant negative effects on growth traits of radish. Accordingly, considering the results of the present research, the decline in the growth traits can be attributed to the decrease in chlorophyll content and photosynthetic indices, which eventually reduce growth. The results of the present study also indicated that perlite particle size also influenced plant growth traits: plant growth traits declined significantly with increases in perlite particle size. In this regard, a study on *Vallisneria natans* showed that biomass production and plant growth traits declined with increases in perlite particle size (Li *et al.,* 2012). The differences in plant growth traits in perlite substrates with different perlite particle sizes can be attributed to the amounts of retained moisture and nutrients.

5.2. Photosynthetic pigments

Nutrition plays a major role in synthesis and accumulation of photosynthetic pigments (Zarco-Tejada *et al.,* 2000). The results of the present study suggested that nutrient deficiency decreased the content of photosynthetic pigments. It was reported in previous studies that the amounts of chlorophyll a, chlorophyll b, and total chlorophyll of olive leaves decreased under conditions of nitrogen deficiency due to the reduction in chlorophyll synthesis and because of its decomposition (Boussadia *et al.,* 2010). The findings of this research demonstrated that the content of chlorophyll in radish leaves decreased under conditions of potassium, nitrogen, and phosphorus deficiencies. Magnesium deficiency lowers leaf chlorophyll content by degrading thylakoid membranes and also via reducing chlorophyll synthesis and degrading chlorophyll molecules (Zhang *et al.,* 2017). Roosta *et al* (2017) reported that the content of photosynthetic pigments in two lettuce cultivars declined under conditions of iron, zinc, and manganese deficiencies. In agreement with the results of the present research, it has also been reported in other studies that sulfur deficiency reduces chlorophyll a and chlorophyll b contents in vetch leaves. The findings of the present study suggested that chlorophyll b and total chlorophyll contents declined significantly in coarse grain perlite substrates. Due to its low water and nutrient holding capacity, perlite decreases availability of nutrients to plants. Consequently, chlorophyll content also decreases. However, chlorophyll content increased when plants grew in perlite substrates together with other substrates capable of retaining more water and nutrients. Accordingly, the reduction in chlorophyll in large perlite substrates can be attributed to the decreased amounts of the nutrients that plants require.

5.3. Chlorophyll-fluorescence indices

Chlorophyll fluorescence is a non-destructive technique for measuring the photosynthetic status of plants and for monitoring their health (Roosta *et al.,* 2017). The results of the present research indicated that nutrient deficiencies significantly decreased chlorophyll-fluorescence indices and the efficiency of the photosynthetic. Researchers have shown that nitrogen deficiency reduces the efficiency of the photosynthetic apparatus and the chlorophyll-fluorescence indices by changing the photochemical efficiency of photosystem II and decreasing the activity of the photosystem II reaction center apparatus

(Zhao *et al.,* 2017). Studies on corn (*Zea mays* L.) reported that nitrogen deficiency reduced the rate of photosynthesis and chlorophyll fluorescence, but the rate of photosynthesis and the efficiency of the photosynthetic apparatus improved with increases in the quantity of nitrogen in the root environment (Jin *et al.,* 2015). It has also been reported that chlorophyll fluorescence indices in corn (*Zea mays* L.) decrease under conditions of potassium deficiency. Potassium deficiency increases leaf temperature and damages cell membrane by changing the anion-cation balance and closing the stomata and, eventually, significantly decreases chlorophyll-fluorescence indices (Zhao *et al.,* 2016). Phosphorus deficiency usually influences the activity of photosystem II reaction centers and decreases the PSII quantum yield and the level of NADP thereby decreasing the amount of energy produced by photosynthesis (Xu *et al.,* 2007). The results of the present research show that potassium deficiency decreases the chlorophyll-fluorescence indices in sweet potato (*Ipomoea batatas* L.) (Liu *et al.,* 2017). In addition, it has been reported that the chlorophyll-fluorescence indices, the efficiency of the photosynthetic apparatus, the quantum yield of the photosynthetic apparatus, and also the number of electrons transferred along the electron transport chain in two lettuce cultivars decrease under conditions of iron, zinc, and manganese deficiencies (Roosta *et al.,* 2017).

5.4. Total soluble sugars

Soluble sugars are among the compounds with roles in osmotic adjustments in plants. Their production increases when plants are under stress conditions. This increase in their production enhances osmotic potential of cells, regulates intracellular osmolarity, and protects biomolecules and membranes (Hossain *et al.,* 2010). The results of the present research demonstrated that leaf soluble sugars increased under conditions of nutrient deficiencies. In agreement with the results of the present research, Boussadia *et al.,* (2010) reported that nitrogen deficiency increased mannitol, glucose, fructose, sucrose, and starch contents in olive leaves. Researchers have reported that nitrogen deficiency prevents carbohydrate loading in the phloem leading to accumulation of soluble sugars in leaves (Boussadia *et al.,* 2010). It has been reported that potassium deficiency increased the contents of soluble sugars in cotton (Zhao *et al.,* 2001). Accumulation of soluble sugars under conditions of potassium deficiency can be attributed to the reduction in the activity of sucrose phosphate synthase. This enzyme plays an important role in distribution of sucrose in plants and in its loading in the phloem. In addition, potassium deficiency increases the activity of invertase and decomposition of sucrose into hexose sugars (6-carbon sugars) (Huber, 1984). A study on soybean showed that the contents of starch and soluble sugars decreased significantly under stress conditions and phosphorus deficiency (Qiu and Israel, 1992). The increase in soluble sugars under conditions of phosphorus deficiency is also attributed to the decrease in sucrose phosphate synthase that enhances sucrose transport to other plant organs and also prevents sucrose decomposition (Qiu and Israel, 1992). In addition, Roosta *et al* (2017) reported that the content of total soluble sugars in two lettuce cultivars significantly increased under conditions of iron, zinc, and manganese deficiencies.

6. Conclusion

Plants need nutrition for growth and survival. Although the minerals form a small amount of a plant’s weight, each of these mineral elements is necessary for carrying out vital activities and the deficiency of these elements leads to plant disturbances which affect the plant’s growth, and ultimately affects the quantity and quality of the product. In the current experiment, it was found that the growth and physiological characteristics of radish were influenced greatly by the size of the perlite particle and nutrient deficiencies. Nutrient deficiencies significantly decreased growth traits of radish. From the above studies we concluded that the small size of perlite is suitable particle for growing radish hydroponically. According to the results of this study, the deficiency of nutrients by reducing the absorption and amount of mineral elements in the plant causes disturbance in the processes of chlorophyll production and photosynthesis, and ultimately affect plant growth and plant function, and it seems that the small size of perlite in substrate was better to absorb the nutrients and therefore suitable for proper growth of radish.

Conflict of interest

The authors have no conflicts of interest.

References

Asaduzzaman, M. d., Kobayashi,Y., Fuad Mondal, M. d., Takuya, B., Histoshi, M., Fumihiko, A., and Toshiki, A. 2013. Growing carrots hydroponically using perlite substrates. Scientia Horticulturae, 159:113-121.

Benton Jones, J. 2005. Hydroponics: A practical guide for the soilless grower. CRC Press, Boca Raton, New Yourk, Washington. D. C. Potassium transport and signaling in higher plants. Annual Review of Plant Biology, 64: 451-476

Boussadia, O., Steppe, K., Zgallai, H., El Hadj, S.B., Braham, M., Lemeur, R. and Van Labeke, M.C. 2010. Effects of nitrogen deficiency on leaf photosynthesis, carbohydrate status and biomass production in two olive cultivars 'Meski'and 'Koroneiki'. Scientia Horticulturae, 123(3): 336-342.

Broadley, M., Brown, P., Cakmak, I., Rengel, Z. and Zhao, F. 2012. Function of nutrients: micronutrients. In Marschner's mineral nutrition of higher plants, Academic Press, 191-248

Broadley, M.R., Escobar-Gutierrez, A.J., Burns, A. and Burns, I.G. 2000. What are the effects of nitrogen deficiency on growth components of lettuce? The New Phytologist, 147(3): 519-526.

Carmona, V. V., Costa, L. C., & Cecílio Filho, A. B. 2015. Symptoms of nutrient deficiencies on cucumbers. International Journal of Plant & Soil Science, 8(6): 1-11.

Cetner, M.D., Kalaji, H.M., Goltsev, V., Aleksandrov, V., Kowalczyk, K., Borucki, W. and Jajoo, A. 2017. Effects of nitrogen-deficiency on efficiency of light-harvesting apparatus in radish. Plant Physiology and Biochemistry, 119: 81-92.

Cheval, C., Aldon, D., Galaud, J.P. and Ranty, B. 2013. Calcium/calmodulin-mediated regulation of plant immunity. Biochimica et Biophysica Acta (BBA)-Molecular Cell Research, 1833(7): 1766-1771.

Epstein E, Bloom AJ (2006). Mineral nutrition of plants: principles and perspectives Londrina: Editora Planta. 402 pages.

Farhat, N., Elkhouni, A., Zorrig, W., Smaoui, A., Abdelly, C. and Rabhi, M. 2016. Effects of magnesium deficiency on photosynthesis and carbohydrate partitioning. Acta physiologiae plantarum, 38(6): 145.

Frias-Moreno, N., Nuñez-Barrios, A., Perez-Leal, R., Gonzalez-Franco, A.C., Hernandez-Rodriguez, A. and Robles-Hernandez, L. 2014. Effect of Nitrogen Deficiency and Toxicity in Two Varieties of Tomatoes (*Lycopersicum esculentum* L.). Agricultural Sciences, 5(14): 1361.

Gonnella, M., and Renna, M. 2021. The evolution of soilless systems towards ecological sustainability in the perspective of a circular economy. Is it really the opposite of organic agriculture? Agron. 11 (5): 950.

Hafsi, C., Debez, A. and Abdelly, C. 2014. Potassium deficiency in plants: effects and signaling cascades. Acta physiologiae plantarum, 36(5): 1055-1070.

Hara, M., Ito, F., Asai T. and Kuboi, T. 2009.Variation in Amylase Activities in Radish (*Raphanus sativus*) Cultivars. Plant Foods for Human Nutrition, 64:188–192.

Hermans, C., Hammond, J.P., White, P.J. and Verbruggen, N. 2006. How do plants respond to nutrient shortage by biomass allocation? Trends in plant science, 11(12): 610-617.

Hossain, M.D., Musa, M.H., Talib, J. and Jol, H. 2010. Effects of nitrogen, phosphorus and potassium levels on kenaf (*Hibiscus cannabinus* L.) growth and photosynthesis under nutrient solution. Journal of Agricultural Science, 2(2): 49.

Hoagland, D. R. and Arnon, D. I. 1950. The water culture method for growing plants without soil. California Agricultural Production Statistics, 347.

Huber, S.C., 1984. Biochemical basis for effects of K-deficiency on assimilate export rate and accumulation of soluble sugars in soybean leaves. Plant Physiology, 76(2): 424-430.

Irigoyen, J., Emerich, DW. and Sánchez-Díaz, M. 1992. Water stress induced changes in concentrations of proline and total soluble sugars in nodulated alfalfa (*Medicago sativa*) plants. Physiol Plantarum 84: 55–60

Jin, X., Yang, G., Tan, C. and Zhao, C. 2015. Effects of nitrogen stress on the photosynthetic CO 2 assimilation, chlorophyll fluorescence, and sugar-nitrogen ratio in corn. Scientific reports, 5: 9311.

Kano, Y., Nakagawa, H., Sekine, M., Goto, H. and Sugiura, A. 2007. Effect of nitrogen fertilizer on cell size and sugar accumulation in the leaves of cabbage (*Brassica oleracea* L.). HortScience, 42(6): 1490-1492.

Li, Y., Wang, T., Li, J. and Ao, Y., 2010. Effect of phosphorus on celery growth and nutrient uptake under different calcium and magnesium levels in substrate culture. Horticultural science, 37(3): 99-108.

Li, Z.Q., Kong, L.Y., Yang, L.F., Zhang, M., Cao, T., Xu, J., Wang, Z.X. and Lei, Y. 2012. Effect of substrate grain size on the growth and morphology of the submersed macrophyte Vallisneria natans L. Limnologica-Ecology and Management of Inland Waters, 42(1): 81-85.

Lichtenthaler, H.K., Wellburn, A.R., 1983. Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. Biochemical Society Transactions, 11: 591–592.

Liu, M., Zhang, A., Chen, X., Jin, R., Li, H. and Tang, Z. 2017. The Effect of Potassium Deficiency on Growth and Physiology in Sweetpotato [*Ipomoea batatas* (L.) Lam.] during Early Growth. HortScience, 52(7): 1020-1028.

Marschner, H., 2011. Marschner's mineral nutrition of higher plants. Academic press.

Petrazzini, L.L., Souza, G.A., Rodas, C.L., Emrich, E.B., Carvalho, J.G. and Souza, R.J. 2014. Nutritional deficiency in crisphead lettuce grown in hydroponics. Horticultura Brasileira, 32(3): 310-313.

Mattson, N.; Merrill, T. *Symptoms of Common Nutrient Deficiencies in Hydroponic Arugula*. eGRO Research Updates. 2017. Available online: http://e-gro.org/pdf/2017-2.pdf

Porra, R.J., Thompson, W.A. and Kriedemann, P.E., 1989. Determination of accurate extinction coefficients and simultaneous equations for assaying chlorophylls a and b extracted with four different solvents: verification of the concentration of chlorophyll standards by atomic absorption spectroscopy. Biochimica et Biophysica Acta (BBA)-Bioenergetics, 975(3): 384-394.

Qiu, J. and Israel, D.W. 1992. Diurnal starch accumulation and utilization in phosphorus-deficient soybean plants. Plant Physiology, 98(1): 316-323.

Reich, M., Shahbaz, M., Prajapati, D.H., Parmar, S., Hawkesford, M.J. and De Kok, L.J. 2016. Interactions of sulfate with other nutrients as revealed by H2S fumigation of Chinese cabbage. Frontiers in plant science, 7.

Riga, P. and Anza, M. 2003. Effect of magnesium deficiency on pepper growth parameters: Implications for determination of magnesium-critical value. Journal of plant nutrition, 26(8): 1581-1593.

Ronen, E. 2016. Micro-elements in agriculture. Practical Hydroponics and Greenhouses, (164), 35.

Roosta, H.R., Estaji, A. and Niknam, F. 2017. Effect of iron, zinc and manganese shortage-induced change on photosynthetic pigments, some osmoregulators and chlorophyll fluorescence parameters in lettuce. Photosynthetica, 1-10.

Sanchez, C.A., Lockhart, M. and Porter, P.S. 1991. Response of radish to phosphorus and potassium fertilization on histosols. HortScience, 26(1): 30-32.

Tzortzakis, N., Nicola, S., Savvas, D., & Voogt, W. (2020). Soilless Cultivation Through an Intensive Crop Production Scheme. Management Strategies, Challenges and Future Directions. Frontiers in Plant Science, 11.

Wei, M., Zhang, A., Li, H., Tang, Z. and Chen, X. 2015. Growth and physiological response to nitrogen deficiency and re-supply in leaf-vegetable sweetpotato (*Ipomoea batatas* Lam). HortScience, 50(5): 754-758.

Xu, H.X., Weng, X.Y. and Yang, Y. 2007. Effect of phosphorus deficiency on the photosynthetic characteristics of rice plants. Russian Journal of Plant Physiology, 54(6): 741-748.

Zarco-Tejada, P.J., Miller, J.R., Harron, J., Hu, B., Noland, T.L., Goel, N., Mohammed, G.H. and Sampson, P., 2000. Needle chlorophyll content estimation through model inversion using hyperspectral data from boreal conifer forest canopies. Remote sensing of environment, 89(2): 189-199.

Zhang, J., Wang, Y., Wang, P., and Zhang, Q., Yan, C., Yu, F., Yi, J. and Fang, L. 2017. Effect of different levels of nitrogen, phosphorus, and potassium on root activity and chlorophyll content in leaves of Brassica oleracea seedlings grown in vegetable nursery substrate. Horticulture, Environment, and Biotechnology, 58(1): 5-11.

Zhao, D., Oosterhuis, D.M. and Bednarz, C.W. 2001. Influence of potassium deficiency on photosynthesis, chlorophyll content, and chloroplast ultrastructure of cotton plants. Photosynthetica, 39(1): 103-109.

Zhao, L.S., Li, K., Wang, Q.M., Song, X.Y., Su, H.N., Xie, B.B., Zhang, X.Y., Huang, F., Chen, X.L., Zhou, B.C. and Zhang, Y.Z. 2017. Nitrogen Starvation Impacts the Photosynthetic Performance of *Porphyridium cruentum* as Revealed by Chlorophyll a Fluorescence. Scientific Reports, 7(1): 8542.

Zhao, X., Du, Q., Zhao, Y., Wang, H., Li, Y., Wang, X. and Yu, H. 2016. Effects of different potassium stress on leaf photosynthesis and chlorophyll fluorescence in Maize (*Zea mays* L.) at seedling stage., Agricultural Sciences, 7:44-53.