Journal of Ornamental Plants
www.jornamental.iaurasht.ac.ir
ISSN (Print): 2821-0093   ISSN (Online): 2783-5219

Research Article
Volume 13, Number 1: 41-51, March, 2023
DOR: https://dorl.net/dor/20.1001.1.28210093.2023.13.1.4.5

Introduction of a Suitable Cultivation Substrate for the Optimal Growth of the Ornamental Plant *Crassula capitella*

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Received: 6 October 2022   **Accepted:** 22 October 2022

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Abstract

The properties of different materials used as planting substrate exert direct and indirect effects on crop growth and production. Hence, the selection of a suitable substrate is one of the most important factors in the success of production in soilless cultivation. The present study aimed to investigate the effects of physical and chemical properties of different cultivation substrates on the growth and development of *Crassula capitella*. Thus, different organic and inorganic cultivation substrates such as sand, coco peat, charcoal, pumice, peat moss and zeolite were combined with each other in different ratios and tested. The measured traits were phytochemical compounds (chlorophyll a, b and total, carotenoid, supeoxide dismutase (SOD) activity level and malondialdehyde (MDA) content), fresh weight and dry weight of root and shoot, and element uptake (nitrogen, phosphorus and potassium). Based on the results of the present research, there was a significant difference in terms of plant height, wet and dry weight, nutrient uptake rate and enzyme activity between different cultivation substrates. The plants grown in substrate (35 cm^3 of fine pumice + 5 cm^3 of coco peat + 5 cm^3 of peat moss + 5 cm^3 of charcoal) and substrate (35 cm^3 of 3-5-mm fine sand + 5 cm^3 of coco peat + 5 cm^3 of charcoal) showed the highest and lowest numerical values of the evaluated traits, respectively. The use of combinations containing pumice, coco peat and zeolites seems to prevent the wastage of nutrients and preserves nutrient ions, and therefore results in increasing the fertilizer efficiency and improving the nutrient uptake and maintaining moisture, and ultimately improves the plant growth.

Keywords: *Crassula capitella*, Pumice, SOD enzyme, Zeolite.

INTRODUCTION

The hydroponic cultivation system has expanded in recent years due to the problems caused by soil cultivation (such as salinity and inappropriate soil structure) and limited water resources in many parts of the world, especially in Iran. Hence, it is very important to apply correct management and advanced methods to maintain moisture storage and increase production (Allah Dadi *et al.*, 2005). Cultivation of plants in alternative soil substrates is expanding due to many advantages, such as the possibility of optimal plant nutrition, reducing the incidence of diseases and pests, and increasing the quantity and quality of the product compared to soil cultivation (Rezaei, 2009; Maloupa *et al*., 2001). Today, these systems use different materials as cultivation substrate, each of which has unique properties (Abad *et al*., 2002; Colla *et al*., 2003; Maloupa *et al*., 2001). The properties of different materials used as planting substrate exert direct and indirect effects on crop growth and production. Hence, the selection of a suitable substrate is one of the most important factors in the success of production in soilless cultivation (Colla *et al*., 2003). These materials include organic, inorganic and artificial materials. These substrates should have a high water holding capacity (WHC), sufficient aeration, proper drainage, and high cation exchange capacity (CEC), and should not have any adverse effects on the plant (Ghasemi *et al*., 2010).

One of the most important strategies to achieve the maximum yield in the minimum time with excellent quality is to grow plants in a soilless greenhouse. Ornamental plants are produced in a greenhouse, which is considered a concentrated system due to increased values of chemical inputs (Lazzerini *et al*., 2016). Because the selection of the optimal substrate for greenhouse crops requires spending large economic costs, each of these substrates should be selected based on economic justification, that is, the production efficiency of that greenhouse product (Ghaemi *et al*., 2009). Therefore, the production of ornamental pot plants is influenced by the components of the growing medium, which usually contains different types of peat and perlite in different ratios (Popescu and Popescu, 2015).

Perlite, coco peat, zeolite, gravel, peat, vermiculite, pumice and sawdust are known as substrates in soilless cultivation (Resh and Howard, 2012). Reportedly, the use of different vegetable composts has had a significant effect on the number and dry weight of leaves in diverse plants (Moldes *et al*., 2007). There are many reports about increasing the height of plants grown in vermicompost produced from different materials compared to the control plant (Rakesh *et al*., 2015). In an experiment, researchers showed that hydroponic substrates containing coco peat had more chlorophyll content than soil substrates, due to higher nitrogen and photosynthesis levels (Wang *et al*., 2018). The use of 5 and 10% vermicompost in the cultivation substrate compared to the combined peat and perlite substrate resulted in an increase in the dry weight of tomato seedlings. In addition, proportions of 20, 30 and 40% vermicompost increased the germination and growth of tomato. This factor reached the maximum in the use of 50% vermicompost, but the seedling weight was significantly reduced in the 100% treatment (Gong *et al*., 2018). In a study on ginger plant (*Zingiber officinale* Rosc.), the combination of 60% municipal waste compost + 20% charcoal + 20% coco peat along with 3 ml/L of fertilizer was introduced as the best substrate in improving the growth indicators (Soeparjono, 2016).

Substrate with high aeration reduces plant growth due to low water accumulation and increased sensitivity to drought. In the comparison of organic substrate, perlite substrates of different sizes and mixed organic-inorganic substrates, extra-fine perlite substrate showed the highest performance in most parameters. The extra-fine perlite substrate with a porosity of 25% and WHC of 33% compared to other organic and inorganic substrates provided suitable physical properties for the root system of geranium (*Pelargonium* spp.). Vermicompost has high porosity, high aeration capacity, proper drainage and high WHC (Gong *et al*., 2018).

Cultivation substrate has had a positive effect on the concentration of mineral substances accumulated in gerbera plant, indicating the uptake of these substances in the plant through the cultivation substrate (Khalaj *et al*., 2014). The mixture of perlite and pumice was reported to be the most suitable substrate; the effect of substrates on flower quality was less than its effect on plant yield. The presence of organic matters and the suitability of the physical and chemical properties of the substrate provide appropriate conditions, such as humidity, aeration, pH and CEC, resulting in an increase in the uptake and storage capacity of nutrients and water. The suitable conditions created for the growth of plant roots improve the quantitative and qualitative traits of the flower as a result of better nutrient uptake, but the use of peat alone is not useful due to compression and reduced aeration. In addition, sand or perlite alone are unsuitable due to the low CEC (Khalaj, 2007). Other researchers also reported the positive effect of peat on tomato growth, and attributed this superiority to the higher level of nutrients in this substrate due to its ability to hold more nutrients and water (Goswami *et al*., 2017).

Succulents are thickened, fleshy, and engorged plants that are very adaptable and have high tolerance to drought and high temperature. Maintaining succulents in the apartment environment is simple (Khaliqi, 1991). The studied succulent has leaves with a red tip and a fleshy green center, which is why it is called red flames with the scientific name *Crassula capitella* (Mushtaghian *et al*., 2017). The current research, which was carried out with the aim of introducing suitable cultivation substrate for succulents, investigated the growth parameters and the degree of nutrient uptake in order to determine the effect of cultivation substrate on nutrient uptake as well as plant growth and development.

MATERIALS AND METHODS

The current research was carried out as a completely randomized design with 10 treatments and 3 replications, aimed at using organic and inorganic substrates with different ratios in the greenhouse of ornamental plants at Dr. Shariati Technical and Vocational College, Tehran, Iran, in the period from April to December 2019 (for eight months). *C. capitella* seeds were obtained from Fadak Gol Lian Company (Iran). The seeds were planted in the planting tray; after germination and initial growth, the seedlings with a height of 3 cm were deployed to pots with a diameter of 8 cm containing the relevant treatments. Each repetition in each treatment included two pots and each pot had one rooted plant. After the plants under different treatments were placed in the appropriate pot, they were randomly deployed next to each other. Irrigation was carried out weekly, with a water volume of 100 cc each time. Although, no weeds were observed in any of the substrate-treated pots during the plants' storage period, necessary care was taken. The conditions of the greenhouse where the pots were kept were 50% humidity during the growth period, the temperature of the greenhouse during the day was 25-27 °C, and the temperature during the night was 18-20 °C, and the available light was 25,000 lux. The treatments were used as follows:

A) Substrate with sand:

1- 130 cc of fine sand + 10 cc of coco peat + 10 cc of charcoal

2- 30 cc of fine sand + 5 cc of coco peat + 10 cc of charcoal

3- 30 cc of fine sand + 15 cc of coco peat + 5 cc of charcoal

4- 25 cc of fine sand + 10 cc of coco peat + 5 cc of peat moss

5- 25 cc of fine sand + 10 cc of coco peat + 10 cc of charcoal + 5 cc of zeolite

B) Substrate with pumice:
1-130 cc of fine pumice + 10 cc of coco peat + 10 cc of charcoal
2- 30 cc of fine pumice + 5 cc of coco peat + 10 cc of charcoal
3- 30 cc of fine pumice + 15 cc of coco peat + 5 cc of charcoal
4- 25 cc of fine pumice + 10 cc of coco peat + 5 cc of peat moss

The measured morphological traits of the plant were the leaf number of each plant, leaf length, leaf width, leaf diameter, stem diameter, plant height, shoot fresh and dry weight, and root fresh and dry weight. The levels of plant pigments, including chlorophylls and carotenoids, were measured according to the proposed method (Lichtenthaler, 1987).

$$\text{Chlorophyll a} = 12.25\times A_{663.2} - 2.79\times A_{646.8}$$
$$\text{Chlorophyll b} = 12.21\times A_{646.8} - 5.1\times A_{663.2}$$
$$\text{Total chlorophyll} = \text{Chlorophyll a} + \text{Chlorophyll b}$$
$$\text{Carotenoides} = (1000(A_{470}) - 1.8 \text{ Chlorophyll a} -85.02 \text{ Chlorophyll b})/198$$

The measured inorganic plant elements were nitrogen and potassium (Emami, 1996) and phosphorus (Black, 1982).

Malondialdehyde (MDA) content was measured by the method (Heath and Packer, 1969).

The level of superoxide dismutase (SOD) enzyme activity was measured by the method (Constantine *et al*., 1977).

After checking the normality of the data distribution and the uniformity of the variance of the test errors, the analysis of variance (ANOVA) was carried out as the completely randomized design.

Statistical calculations were performed by SAS software. In the first step, a simple analysis of variance was performed for the measured traits and then the average values of the studied traits were compared using the LSD test at a level of 5% probability. Finally, simple correlation coefficients between traits were determined by Pearson method.

RESULTS

In the present study, the morphological traits of *C. capitella* measured were the leaf number, stem diameter, plant height, leaf length, leaf width, reproduction, fresh weight and dry weight of shoot and root (Tables 1 and 2).

Table 1. The results of analysis of variance test for the effect of different cultivation substrates on morphological traits of succulent plants.

S.o.V	df	MS					
		Leaf number	Stem diameter	Plant height	Leaf length	Leaf width	Reproduction
Treatment	9	551.54**	0.93**	201.93**	10.76**	0.37**	20.06**
Test error	20	12.	0.004	0.6	0.36	0.003	0.47
CV (%)	-	3.07	5.7	3.73	11.15	5.89	18.3

**: Significant at P < 0.01 based on the LSD test, respectively.

Table 2. Comparison of the mean values of parameters related to different cultivation substrates on the morphological traits of the succulent plant.

Substrates	Leaf number	Leaf length (cm)	Leaf width (cm)	Stem diameter (mm)	Plant height (cm)	Reproduction
1	15.60j	2.50h	0.43f	0.37i	6.67j	0.00g
2	25.00h	3.83fg	0.67e	0.60h	150h	1.67ef
3	22.33i	3.17gh	0.5f	0.53h	12.33i	1.00fg
4	28.00g	4.50ef	0.73e	0.77g	17.33g	2.33de
5	31.67f	5.17de	0.87d	0.93f	19.00f	3.00cd
6	37.67e	5.67cd	1.00c	1.20e	22.67e	3.67c
7	47.00c	6.67bc	1.23b	1.60c	28.00c	6.33a
8	41.33d	6.33c	1.07c	1.37d	24.33d	5.00b
9	50.67b	7.50ab	1.30b	1.73b	30.00b	7.00a
10	58.00a	8.33a	1.50a	2.00a	32.33a	7.33a

*In each column, means with similar letter(s) are not significantly different ($P < 0.05$) using the LSD test. (1) 30 cc of fine sand + 10 cc of coco peat + 10 cc of charcoal, (2) 30 cc of fine sand + 5 cc of coco peat + 10 cc of charcoal, (3) 30 cc of fine sand + 15 cc of coco peat + 5 cc of charcoal, (4) 25 cc of fine sand + 10 cc of coco peat + 5 cc of peat moss, (5) 25 cc of fine sand + 10 cc of coco peat + 10 cc of charcoal + 5 cc of zeolite, (6) 30 cc of fine pumice + 10 cc of coco peat + 10 cc of charcoal, (7) 30 cc of fine pumice + 5 cc of coco peat + 10 cc of charcoal, (8) 30 cc of fine pumice + 15 cc of coco peat + 5 cc of charcoal, (9) 25 cc of fine pumice + 10 cc of coco peat + 5 cc of peat moss, (10) 25 cc of fine pumice + 10 cc of coco peat + 10 cc of charcoal + 5 cc of zeolite.

Table 3. The results of analysis of variance test for the effect of different cultivation substrates on the fresh weight and dry weight of the succulent plants.

S.o.V	df	Shoot fresh weight (SFW)	Shoot dry weight (SDW)	SFW/ SDW	Root fresh weight (RFW)	Root dry weight (RDW)	RFW/ RDW
Treatment	9	7.06**	7.62**	0.03**	8.61**	2.19**	0.013**
Test error	20	0.03	0.01	0.0002	0.02	0.001	0.0007
CV (%)	-	0.55	0.50	0.65	0.83	0.47	1.8

**: Significant at $P < 0.01$ based on the LSD test.

Table 4. Comparison of the mean values of parameters related to different cultivation substrates on the fresh weight and dry weight of the succulent plants.

Substrates	Shoot fresh weight (SFW) (g)	Shoot dry weight (SDW) (g)	SFW/ SDW	Root fresh weight (RFW) (g)	Root dry weight (RDW) (g)	RFW/ RDW
1	29.50h	13.88j	2.12a	14.93j	6.27j	2.38cd
2	32.80f	16.32h	2.01c	17.47h	7.17h	2.44b
3	32.33g	15.55i	2.08b	17.00i	6.72i	2.53a
4	33.35e	17.25g	1.93d	17.90g	7.52g	2.38cd
5	33.48de	17.60f	1.90e	18.60f	7.73f	2.41bc
6	33.70cd	17.82e	1.89e	18.95e	7.93e	2.39cd
7	34.27b	18.48c	1.85fg	19.78c	8.47c	2.34ef
8	33.92c	18.15d	1.87f	19.40d	8.22d	2.36de
9	34.58a	18.70b	1.85fg	20.10b	8.68b	2.31f
10	34.85a	18.95a	1.84g	20.55a	8.88a	2.31f

*In each column, means with similar letter(s) are not significantly different ($P < 0.05$) using the LSD test.

Table 5. The results of analysis of variance test for the effect of different cultivation substrates on the pigments of succulent plants.

S.o.V	df	Chlorophyll a	Chlorophyll b	Total chlorophyll	Carotenoids
Treatment	9	0.11*	0.004**	0.004**	3.36**
Test error	20	0.04	0.00004	0.0003	0.13
CV (%)	-	15.62	5.80	7.21	3.59

*and **: Significant at $P < 0.05$ and $P < 0.01$ based on the LSD test, respectively.

Table 6. Comparison of the mean values of parameters related to different cultivation substrates on the pigments of succulent plants.

Substrates	Chlorophyll a (mg/g F.W.)	Chlorophyll b (mg/g F.W.)	Total chlorophyll (mg/g F.W.)	Carotenoids (mg/g F.W.)
1	0.070b	0.047g	0.177h	8.26i
2	0.100b	0.077e	0.207fg	9.00gh
3	0.090b	0.063f	0.193gh	8.63hi
4	0.110b	0.093	0.217efg	9.32fg
5	0.117b	0.103cd	0.230def	9.67ef
6	0.127b	0.110c	0.237cde	10.02de
7	0.157ab	0.130b	0.263bc	10.70bc
8	0.143b	0.123b	0.250bcd	10.38cd
9	0.163a	0.143a	0.277ab	11.05ab
10	0.177a	0.153a	0.297a	11.48a

*In each column, means with similar letter(s) are not significantly different ($P < 0.05$) using the LSD test.

Table 7. The results of analysis of variance test for the effect of different cultivation substrates on the nutrient uptake, MDA content and SOD activity of succulent plants.

S.o.V	df	Nitrogen	Potassium	Phosphorus	SOD	MDA
Treatment	9	4529.32**	3.36**	0.16**	28805.65**	7964.28**
Test error	20	3.30	0.29	0.0003	110.83	18.67
CV (%)	-	1.34	2.12	0.54	0.78	3.27

**: Significant at $P < 0.01$ based on the LSD test.

Table 8. Comparison of the mean values of parameters related to different cultivation substrates on the nutrient uptake, MDA content and SOD activity of succulent plants.

Substrates	Nitrogen (mg/g)	Potassium (mg/g)	Phosphorus (mg/g)	SOD (IU/mg protein)	MDA (IU/mg protein)
1	81.00j	23.65h	2.67i	1180.00i	44.33j
2	100.33h	24.43fgh	2.96g	1275.00g	95.00h
3	91.33i	24.07gh	2.86h	1226.67h	72.67i
4	119.00g	24.80efg	3.04f	1308.33f	112.33g
5	129.67f	25.07def	3.13e	1346.67e	126.33f
6	141.00e	25.42cde	3.16e	1376.67d	145.33e
7	163.67c	26.15abc	3.29c	1413.33c	174.33c
8	154.67d	25.73bcd	3.24d	1391.67d	162.67d
9	181.00b	26.45ab	3.35b	1450.00b	188.00b
10	197.67a	26.90a	3.41a	1486.67a	201.67a

*In each column, means with similar letter(s) are not significantly different ($P < 0.05$) using the LSD test.

Based on the results of analysis of variance test, the effect of cultivation substrate treatments on leaf number, leaf length, leaf width, stem diameter, plant height, reproduction, shoot fresh weight, shoot fresh to dry weight ratio, chlorophyll b content, total chlorophyll, nitrogen uptake level, potassium uptake level, phosphorus uptake level, MDA content and SOD activity level were significant at 1% probability level (Tables 1, 3, 5 and 7).

Based on the results of analysis of variance test, shoot dry weight and chlorophyll a content under the effect of different cultivation substrate treatments showed a significant difference at the 5% probability level (Tables 1 and 5).

DISCUSSION

To date, many researches have been carried out on the augmentation of various compounds, including animal manures, superabsorbents (pumice) and zeolites, in order to increase the quality of the soil and to have a greater effect on the consumption of fertilizers and nutrients, and finally to increase the yield and yield components of crops. Zahedi *et al*. (2009) investigated the effects of zeolite application on the growth, yield and yield components of rapeseed under normal and drought stress conditions, and found that the administration of zeolite (10 t/ha) significantly increased the height of the rapeseed plant from 88.37 cm (without zeolite treatment) to 95.93 cm, indicating an increase of 8.8% in the plant height. These researchers believe that zeolite, by improving soil CEC, causes better and easier plant access to water and nutrients, especially nitrogen, and therefore increases vegetative growth and plant height (Zahedi *et al*., 2009). In the present study, the substrate No. 10 (25 cc of fine pumice + 10 cc of coco peat + 10 cc of charcoal + 5 cc of zeolite) increased plant height compared to other treatments, in line with the findings of other researchers.

Ranjbar *et al*. (2004) investigated the effects of irrigation and natural zeolite on quantitative and qualitative yield of tobacco (*Nicotiana tabacum* var. Coker 347), and showed that the effect of zeolite on plant height, dry weight, sugar content and nicotine content was statistically significant at the 1% level, and the treatment of 25 g of zeolite and 50% moisture depletion was the best treatment for the production of this product (Ranjbar *et al*., 2004).

By evaluating municipal solid waste compost, peat and pine bark compost as plant cultivation substrate while application in a mixed substrate design on wheatgrass and barley, the highest shoot dry weight of the plant was obtained from the substrate mixture of municipal solid waste compost with pine bark, compared to the mixture of municipal solid waste compost with peat (Moldes *et al*., 2007). In the present study, the substrate No. 10 (25 cc of fine pumice + 10 cc of coco peat + 10 cc of charcoal + 5 cc of zeolite) could increase the fresh weight and dry weight of *C. capitella*, in line with the results of other researchers.

Alifar *et al*. (2010) investigated the yield of greenhouse cucumber in the cultivation substrates of coco peat, perlite and peat moss, and found that there was no significant difference in the yield of cucumber between different cultivation substrates. A significant difference (at the level of 5%) was observed in plant biomass, so that the highest plant biomass was obtained in the cultivation substrate of coco peat and perlite-coco peat. The researchers documented that the combination of compost (20+80) in the waste from pruning plants and sewage sludge with ratios of 25 and 50% could be a substitute for peat in the cultivation substrate of seasonal seedlings, including parsley, sage and begonia (Grigatti *et al*., 2007). In the investigation and comparison of date leaf compost with peat as a cultivation substrate, the results revealed that the number of germinated seeds as well as the growth indices of dahlia, parsley, zinnias and cosmos plants in date leaf compost were equal or greater than peat (Ali, 2008). Additionally, some studies reported that organic waste such as municipal waste, sewage sludge, animal and livestock manure, paper, pruning waste and mushroom substrate and any other green waste after composting can replace peat in cultivation substrate, and can provide satisfactory result (Gayasinghe *et al*., 2010).

Morphological traits

The consumption of pumice and zeolite can increase the final yield of the plant by providing water and nutrients needed by the plant. Gholizadeh *et al*. (2010) found that increasing the dosage of these compounds resulted in increasing the level of nitrogen uptake and therefore increasing the levels of nucleic acids, amides and amino acids, ultimately increasing the leaf area (Gholizadeh *et al*., 2010). In an experiment, the effect of vermicompost obtained from cow dung on the growth of parsley was investigated, and the data showed that the maximum stem diameter, flower size, fresh weight and dry weight of the stem were obtained in the substrate containing 60% vermicompost + 30% sand + 10% soil, and the maximum plant height was found in the substrate containing 60% peat + 40% perlite, but the growth of plants was better in cow dung vermicompost than peat (Shadanpour *et al*., 2011).

The plant height is one of the important morphological components of the plant, which acts as a main indicator to determine the rate of access to environmental resources for plant growth. The height of a plant depends on the availability of water and nutrients, especially nitrogen (Ferdous, 2001).

Levels of plant inorganic elements

There was no significant difference in nitrogen, potassium and magnesium concentration between cucumber plants grown in different substrates. However, the highest concentration of nitrogen and potassium in the second and third stages of sampling was observed in Coco peat. Plant magnesium in the first and second stages of sampling was higher than the critical concentration of its deficiency in all substrates. In general, the best concentration of nutrients and yield was obtained in the cultivation substrate of coco peat, which can be used as a suitable cultivation substrate for cucumbers in hydroponic systems (Alifar *et al*., 2010). In the present research, the effect of cultivation substrate on nutrient uptake rate of succulent plant was positive.

Levels of plant pigments

Although, environmental conditions such as light and temperature have a significant effect on pigment levels (Znidarcic and Pozrl, 2006), the type of substrate also affects the pigment index (Ahmadi Dahaj *et al*., 2012). The significant effect of substrate in soilless cultivation of lettuce on the content of chlorophyll a and chlorophyll b has been previously reported (Siomos *et al*., 2001). In another study, researchers showed that the application of compost significantly improved the chlorophyll content, protein content and Rubisco capacity in barley plants (Lakhdar *et al*., 2016).

Researchers investigated cotton waste compost as a cultivation substrate to replace peat in croton cultivation, and observed that the increase of compost (*Codiaem variegatum*) up to 75% had no effect on the growth indicators compared to the control, but the amount of red pigment on the leaf surface increased, which is related to the increase in anthocyanin concentration, but 25% replacement increased the dry weight of the plant (Papafotiou *et al*., 2005). In line with the findings of other researchers, we found that cultivation substrate had a different effect on the levels of plant pigments, so that the results suggested substrate No. 10 (25 cc of fine pumice + 10 cc of coco peat + 10 cc of coal + 5 cc of zeolite) for the production of studied plants.

CONCLUSION

The specific structural properties of zeolite and pumice, due to having many pores, help to improve soil aeration conditions in the long term, which is beneficial for proper plant growth and soil biological activities.

Based on the results of the present research, there was a significant difference in plant height, wet dry, dry weight, nutrient uptake rate, SOD activity level and MDA content between different cultivation substrates. The *Crassula capitella* plants grown in substrate No. 10 (35 cc of fine pumice + 5 cc of coco peat + 5 cc of peat moss + 5 cc of charcoal) and substrate No. 1 (35 cc of 3-5-mm fine sand + 5 cc of coco peat + 5 cc of charcoal) showed the highest and lowest numerical values of the evaluated traits, respectively.

The use of combinations containing pumice, coco peat and zeolites seems to prevent the wastage of nutrients and preserves nutrient ions, and therefore results in increasing the fertilizer efficiency and improving the nutrient uptake and maintaining moisture, and ultimately improves the plant growth.

ACKNOWLEDGMENT

The authors declare that they have no conflict of interest.

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How to cite this article:

Kiani, H., Khakipour, N., Kalatehjari, S., & Saeedi Sar, S. (2023). Introduction of a Suitable Cultivation Substrate for the Optimal Growth of the Ornamental Plant *Crassula capitella*. Journal of Ornamental Plants, 13(1), 41-51.

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