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Different Ratios of Vermicompost in Planting Substrates Affect the Growth and Physiological Characteristics of Spathiphyllum (*Spathiphyllum wallisii*)

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ABSTRACT

Spathiphyllum (*Spathiphyllum Wallisii*) is a member of the Araceae family. To investigate the effect of different planting substrates and varying levels of vermicompost on the growth and physiological traits of Spathiphyllum under greenhouse conditions, an experiment was conducted in a factorial design within a completely randomized layout. The experiment comprised 16 treatments, with each treatment replicated four times. In this experiment, factor A included four levels of planting substrate (sand + perlite, sand + peat, peat + perlite, peat + perlite + sand), and factor B included four levels of vermicompost (0%, 25%, 50%, and 75% by volume of the pot). The results obtained from the experiment indicated that the interaction effect of planting substrates and vermicompost on important traits such as the number of leaves on the plant, length and width of the spathe, fresh and dry weight of the offshoot, and the concentrations of chlorophyll, nitrogen, and iron in the leaves was significant. Specifically, using peat + perlite + sand (all in a ratio of 8.3 by volume of the pot) combined with 75% vermicompost resulted in the highest values for leaf length, spathe length, number of roots in the offshoot, chlorophyll content in the leaves, nitrogen content in the leaves, and iron content in the leaves, showing 20 to 30 percent higher effects compared to all other treatments. Conversely, the treatment of 50% perlite + 50% sand without using vermicompost exhibited the lowest values across all mentioned traits. Therefore, the use of peat + perlite + sand (all in a ratio of 8.3 by volume of the pot) combined with 75% vermicompost is recommended as the optimal substrate for the cultivation of Spathiphyllum.

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1. Introduction

Spathiphyllum (*Spathiphyllum Wallisii*) is an evergreen and tropical plant native to Colombia (Sailaja *et al*., 2024). It is a rosette, stemless plant that is cultivated for both its decorative leaves and its unusual flowers (Saneei Shariat Panahi, 2008). Spathiphyllum belongs to the family of Araceae. This species is the most well-known houseplant of the Spathiphyllum, reaching heights of 30–40 cm. It features elongated, lance-shaped leaves that are glossy green and white flowers that form a spike, measuring about 5–10 cm in length. The flowers are white, each consisting of a flat spathe-like part and a tubular, curved part that is initially yellow and later turns green. This spike is covered by an egg-shaped white spathe. Flowering occurs in spring and summer, and it can be forced to bloom in winter under favorable conditions in a greenhouse (Khalighi, 1997; Safeena *et al*., 2023). Soils with suitable structure and loamy texture are the most desirable and best types of soil. Greenhouse products can often be grown in fields without significant changes, but when this soil is transferred to containers and the same product is cultivated, it fails. This is because the aeration in these containers is often insufficient. Therefore, by adding organic matter to the soil, the soil structure can be improved, and aeration can be increased without reducing the water retention capacity (Nelson, 1987; Rabiya, 2024). Soil often contains a small amount of organic material and varies in terms of mineral content, such as clay, silt, and sand. Nowadays, the use of soil is declining for various reasons. Some of these reasons include the unavailability of suitable soil, its heavy weight and related transportation issues, poor soil aeration. Various substrates can be used in growing media (Dole *et al*., 1999), which can be divided into two categories: Organic substrates: These include various types of peat, tree bark, sawdust, wood, animal manure, different kinds of compost, and processed waste. Mineral substrates: These include perlite, vermiculite, polystyrene, rock wool, dried clay, sand, and gravel. The use of cultural substrate began in the 1960s with organic substrates like peat (Schwars, 1985). Organic substrates have chemical and physical properties that differentiate their applications from mineral substrates. For example, sphagnum peat and pine bark possess certain absorptive and surface adsorption characteristics, making these substrates more similar to soil, whereas inorganic substrates such as sand, perlite, or rock wool lack such properties. Organic substrates have buffering capacity, which can benefit producers as a storage mechanism for essential nutrients elements and reduce the likelihood of nutrient elements deficiencies or excesses. Furthermore, organic materials used as cultural substrate may contain sufficient amounts of certain elements required by plants, thus fulfilling their needs and reducing the reliance on chemical solutions. Additionally, the low cost and availability of organic substrates are among their advantages (Yahyaabadi, 2009).

Peat is a type of soil formed from the semi-decayed remains of aquatic or marsh plants that have been subaquatic over time in bogs. The lack of oxygen slows down the bacterial and chemical decomposition of plant materials. The composition of different peats varies based on the types of plants from which they originated their mineral content, and their acidity level. Peats are formed from the remains of plants that died hundreds of years ago and have been buried in layers on top of one another. In fact, the formation of a one-millimeter layer of compressed peat requires a year's growth of the plants that make it up (Bunt, 1998). Furthermore, since obtaining this material for use in growing media is equivalent to destroying wetland areas or peat habitats, researchers are seeking suitable alternatives for its use in plant growing media (Adams *et al*., 1997). There are various types of peat, which have a fibrous texture and high porosity. They have a high water retention capacity and acidic pH. Different types of peat are widely used in gardening (Nelson, 1987; Dole *et al*., 1999; Adams *et al*., 1997). If the peat is completely dry beforehand, wetting it can initially be difficult and time-consuming (Nell *et al*., 1997). This issue can be resolved by adding wetting agents or warm water to the growing medium. Due to their acidity, peats have medium to low Cation Exchange Capacity (CEC). Their pH ranges from 3 to 4, and they have a low bulk density. The C/N ratio in them is 50 to 1, and decomposition occurs slowly, which does not create nitrogen deficiency issues in the plant growing medium (Dole *et al*., 1999). Types of peat include Peat moss (sphagnum peat), reed-sedge peat, humus peat, coconut peat (Cocopeat), and palm peat.

Perlite, a silicate material of volcanic origin, is grayish-white and used in gardening for its water absorption capacity (3 to 4 times its weight). This material is essentially neutral and, unlike vermiculite, lacks cation exchange capacity and mineral nutrient properties. Perlite can cause problems for plants that are sensitive to fluoride. Its best use is in increasing aeration in soil mixtures. Perlite, when combined with sphagnum peat, is one of the most common rooting mediums for cuttings (Khoshkhui, 2002; Petre *et al*., 2015). Perlite is much more expensive than sand, but it is lighter. When used in substrate, it significantly aids in aeration (Dole *et al*., 1999). Washing the growing medium before use, reducing the use of phosphate in the growing medium, and adjusting the pH of the growing medium to between 6 and 6.5 can mitigate this risk. Perlite has low bulk density, and during watering, its particles tend to float to the top of the growing medium, which can create problems (Bunt, 1998). Adding perlite to soil is primarily for improving soil aeration. Perlite is widely used as a rooting medium for leafy cuttings, especially in mist systems, due to its excellent drainage properties. It can be used alone but is often combined in appropriate amounts with peat or vermiculite (Khoshkhui, 2002).

Sand holds special value for rooting plants because cuttings taken from plants have enough stored nutrients. Its value lies in having adequate porosity, the presence of oxygen, moisture retention, and being widely used as a rooting medium for cuttings; it is inexpensive and readily available. Sand does not retain moisture and requires frequent watering. For evergreen trees, sand is the most satisfactory rooting medium; however, for some species, cuttings rooted in sand produce long, brittle roots without branching, which contrasts with the desirable fibrous and branched roots obtained in other growing media (Khoshkhui, 2002).

Years of effort and studies, along with various research and experiments, have shown that earthworm has provided one of the primary needs for plant growth media: organic matter through its waste. Vermicompost is the product of the biological activity of a type of earthworm scientifically known as *Eisenia foetida*. It converts organic materials found in nature into nutrient-rich organic fertilizer, which is now recognized globally as one of the richest sources of biological organic fertilizers. Vermicompost has a significant impact on the physical, chemical, and biological properties of soil. This fertilizer improves the physical, chemical, and biological characteristics of the soil and, in addition to its low bulk density, is odorless and free of pathogenic microorganisms, anaerobic bacteria, fungi, and weeds. Vermicompost, besides having a high water absorption capacity, provides suitable conditions for granulation and the ability to retain nutrients needed by plants. It contains highly enriched nutrient elements, especially nitrogen, which it gradually makes available to the plants. Compared to other organic fertilizers, vermicompost has a higher concentration of essential nutrient elements. In addition to macronutrients like nitrogen, phosphorus, and potassium, which play critical roles in the vital activities of plants, it also contains micronutrients such as iron, copper, zinc, and manganese. Furthermore, it provides growth-promoting factors with substances like vitamin B12 and auxins (Blouin *et al*., 2019; Tomati *et al*., 1988). The length of its dry particles ranges from 1 to 5 mm.

The most valuable feature of vermicompost is the presence of various enzymes, microorganisms, and hormones. Vermicompost contains enzymes such as protease, amylase, lipase, cellulase, and chitinase, which play a significant role in the decomposition of organic materials in the soil and, consequently, in making essential nutrients available to plants. It creates a suitable growth environment for plants, leading to increased yields (Edwards, 1997; Olle, 2016). Numerous studies have emphasized the importance of vermicompost in agriculture and the cultivation of horticultural and ornamental plants. Vermicompost is rich in microbial populations, especially fungi, bacteria, actinomycetes, yeasts, and algae, which play a crucial role in providing nutrients and promoting plant growth (Olle, 2016; Edwards and Burrows, 1997). Research has shown that vermicompost can positively affect ornamental plant growth by increasing water retention capacity, supplying nutrient elements, and producing plant hormones that have a beneficial effect on seed germination. Studies indicate that the use of vermicompost in transplanting vegetable leads to enhanced growth of these plants (Lim *et al*., 2015; Bachman and Metzeger, 1998).

Considering the significance of cultivating Spathiphyllum as a houseplant and the substantial impact of using organic substrates compared to mineral substrates on the quantitative and qualitative characteristics of various plants, including ornamental plants—especially Spathiphyllum—this research aimed to improve the cultivation of this flower by pursuing the following objectives: 1. To investigate the use of various planting substrates for the growth and production of offshoots in Spathiphyllum. 2. To examine the effect of different levels of vermicompost on the growth and production of offshoots in Spathiphyllum. 3. To explore the cumulative interactive effects of different planting substrates combined with vermicompost on the growth and production of offshoots and the concentrations of nitrogen and iron in Spathiphyllum.

2. Materials and methods

2.1. Greenhouse condition

This research was conducted in the ornamental plants greenhouse of Islamic Azad University, Jiroft Branch. The city of Jiroft is located at an altitude of 627 meters above sea level, at a longitude of 57 degrees and 25 minutes north and a latitude of 27 degrees and 30 minutes east. The average annual rainfall is 140 mm, with a maximum temperature of 48 ºC, a minimum temperature of 1 degree Celsius, and humidity levels ranging from 55% to 65%. The temperature and humidity in this greenhouse were actively controlled and managed.

2.2. Plant Material

In this experiment, offshoots of Spathiphyllum were sourced from the greenhouse at Islamic Azad University, Jiroft. Care was taken to ensure that all cultivated flowers were uniform in size and weight.

2.3. Description of the Experiment

To investigate the effects of different planting substrates and various levels of vermicompost on the growth and physiological traits of Spathiphyllum under greenhouse conditions, an experiment was conducted in a factorial design within a completely randomized layout. In this experiment, factor A included different planting substrates (sand + perlite, sand + peat, peat +

perlite, peat + perlite + sand). In contrast, factor B consisted of four levels of vermicompost (0, 25, 50, and 75% by pot volume). The study was carried out with 16 treatments and four replications, totaling 64 identical and uniformly sized pots.

Table 1. Determined ratios for planting substrates and vermicompost based on the volume ratio of the pot and their weight amounts.

Treatments	Volume Ratio (%)	Weight Amount (g)
Vermicompost	0	0
	25	335
	50	670
	75	1005
Peat	8.3	69.7
	12.5	105
	16.6	139.4
	25	210
	33.3	279.7
	37.5	315
	50	420
Perlite	8.3	28.2
	12.5	42.5
	16.6	56.4
	33.3	113.9
	37.5	127.5
	50	170
Sand	8.3	194.2
	12.5	292.5
	16.6	388.5
	33.3	780
	37.5	877.5
	50	1170

Twelve pots of spathiphyllum were obtained from the ornamental plants greenhouse of Islamic Azad University, Jiroft. Plastic pots with a diameter of 16 cm and a height of 20 cm were used for this research. Initially, based on the planting map (Table 2), the specified ratios of substrates and vermicompost were mixed according to the required volumetric ratios calculated based on the volume occupied by the pots (Table 1). The mixture was filled to a height of 18 centimeters in the pots (leaving 2 centimeters empty at the top), and then the offshoots were planted.

The substrates used in this experiment were washed sand, perlite, and date palm peat, and the vermicompost was derived from processed cow manure by *Eisenia foetida* worms (Table 2). The pots were irrigated using a spray system, and other necessary factors, such as the greenhouse environment and micronutrient feeding, were kept uniform for all pots. Additionally, to prevent clogging of the drainage holes, the bottom 2 cm of the plastic pots were filled with gravel.

Figure 1: Planting substrates.

Figure 2: Seedlings of spathiphyllum used in the experiment.

Figure 3: View of the design.

Figure 4: Measurement of the flower width.

Figure 5: Measurement of SPAD in leaf.

2.4. Measurement of growth parameters

The number of offshoots formed was counted after removing the flowers from the pots. A sharp knife was used to detach the offshoots from the plant, along with their roots. The width and length of the spathe were measured using digital calipers, and the data were accurately recorded in the corresponding tables. To measure the fresh and dry weights of the offshoots, the entire plant from each pot was carefully removed from the planting substrate. To minimize root damage and facilitate the complete extraction from the substrate, the pots were watered beforehand to ensure they were fully saturated, allowing the roots to be removed with minimal injury. The roots were then washed with water pressure, and after some time, the fresh weight of the offshoots was measured using a digital scale with an accuracy of 0.01 g. The samples were then placed in an oven at 75 ºC for 24 hours to dry, after which their dry weights were measured.

Table 2: Planting Map of the Experiment Design

First Replication	Second Replication	Third Replication	Fourth Replication
Peat 50% + Sand 50% + Vermiculite 0%	Perlite 37.5% + Sand 37.5% + Vermiculite 25%	Peat 16.6% + Perlite 16.6% + Sand 16.6% + Vermiculite 50%	Perlite 50% + Sand 50% + Vermiculite 0%
Perlite 50% + Sand 50% + Vermiculite 0%	Peat 50% + Perlite 50% + Vermiculite 0%	Perlite 50% + Sand 50% + Vermiculite 0%	Peat 50% + Perlite 50% + Vermiculite 0%
Perlite 37.5% + Sand 37.5% + Vermiculite 25%	Peat 12.5% + Perlite 12.5% + Vermiculite 75%	Perlite 37.5% + Sand 37.5% + Vermiculite 25%	Peat 33.3% + Perlite 33.3% + Sand 33.3% + Vermiculite 0%
Peat 50% + Perlite 50% + Vermiculite 0%	Perlite 50% + Sand 50% + Vermiculite 0%	Peat 50% + Sand 50% + Vermiculite 0%	Perlite 25% + Sand 25% + Vermiculite 50%
Peat 25% + Sand 25% + Vermiculite 50%	Peat 25% + Perlite 25% + Vermiculite 50%	Peat 50% + Perlite 50% + Vermiculite 0%	Peat 12.5% + Perlite 12.5% + Vermiculite 75%
Perlite 25% + Sand 25% + Vermiculite 50%	Peat 50% + Sand 50% + Vermiculite 0%	Perlite 25% + Sand 25% + Vermiculite 50%	Perlite 37.5% + Sand 37.5% + Vermiculite 25%
Peat 12.5% + Sand 12.5% + Vermiculite 75%	Perlite 25% + Sand 25% + Vermiculite 50%	Peat 12.5% + Sand 12.5% + Vermiculite 75%	Peat 25% + Sand 25% + Vermiculite 50%
Peat 25% + Perlite 25% + Vermiculite 50%	Peat 16.6% + Perlite 16.6% + Sand 16.6% + Vermiculite 50%	Peat 25% + Sand 25% + Vermiculite 50%	Peat 25% + Perlite 25% + Sand 25% + Vermiculite 25%
Perlite 12.5% + Sand 12.5% + Vermiculite 75%	Peat 25% + Sand 25% + Vermiculite 50%	Perlite 12.5% + Sand 12.5% + Vermiculite 75%	Perlite 12.5% + Sand 12.5% + Vermiculite 75%
Peat 16.6% + Perlite 16.6% + Sand 16.6% + Vermiculite 50%	Peat 37.5% + Sand 37.5% + Vermiculite 25%	Peat 37.5% + Perlite 37.5% + Vermiculite 25%	Peat 16.6% + Perlite 16.6% + Sand 16.6% + Vermiculite 50%
Peat 37.5% + Perlite 37.5% + Vermiculite 25%	Peat 12.5% + Sand 12.5% + Vermiculite 75%	Peat 25% + Perlite 25% + Sand 25% + Vermiculite 25%	Peat 50% + Sand 50% + Vermiculite 0%
Peat 37.5% + Sand 37.5% + Vermiculite 25%	Peat 8.3% + Perlite 8.3% + Sand 8.3% + Vermiculite 75%	Peat 37.5% + Sand 37.5% + Vermiculite 25%	Peat 12.5% + Sand 12.5% + Vermiculite 75%
Peat 25% + Perlite 25% + Sand 25% + Vermiculite 25%	Peat 25% + Perlite 25% + Sand 25% + Vermiculite 25%	Peat 33.3% + Perlite 33.3% + Sand 33.3% + Vermiculite 0%	Peat 8.3% + Perlite 8.3% + Sand 8.3% + Vermiculite 75%
Peat 8.3% + Perlite 8.3% + Sand 8.3% + Vermiculite 75%	Perlite 12.5% + Sand 12.5% + Vermiculite 75%	Peat 8.3% + Perlite 8.3% + Sand 8.3% + Vermiculite 75%	Peat 37.5% + Perlite 37.5% + Vermiculite 25%
Peat 12.5% + Perlite 12.5% + Vermiculite 75%	Peat 37.5% + Perlite 37.5% + Vermiculite 25%	Peat 25% + Perlite 25% + Vermiculite 50%	Peat 25% + Perlite 25% + Vermiculite 50%
Peat 33.3% + Perlite 33.3% + Sand 33.3% + Vermiculite 0%	Peat 33.3% + Perlite 33.3% + Sand 33.3% + Vermiculite 0%	Peat 12.5% + Perlite 12.5% + Vermiculite 75%	Peat 37.5% + Sand 37.5% + Vermiculite 25%

2.5. Measurement of nitrogen and iron in leaves

To measure the nitrogen content in the leaves, 0.3 g of the plant sample was weighed and transferred to digestion tubes. A mixture of sulfuric acid and salicylic acid was added, and the samples were left for 24 hours. Afterward, the samples were transferred to a thermoblock, where they were oxidized using heat and hydrogen peroxide, resulting in a clear liquid. The solution was then brought to a volume of 50 ml, and the total nitrogen content of the samples was measured using the Kjeldahl method. For measuring iron in the leaves, the sample was first burned using the dry digestion method in an electric furnace at a temperature of 580 ºC, then dissolved in hydrochloric acid, and read using atomic absorption spectroscopy (Amami, 1996).

2.6. Measurement of leaf chlorophyll

The chlorophyll content was measured by randomly sampling mature leaves and extracting them with acetone. First, 0.25 g of fresh leaves were chopped and crushed in a porcelain mortar with 10 mL of acetone until a uniform paste was obtained. The resulting mixture was then transferred to 20-mL falcon tubes and centrifuged at 3500 rpm for 10 minutes. The absorbance of the supernatant solution was measured using a "T 80UV/VIS Spectrometer model PG Instruments Ltd" at wavelengths of 645 and 663 nanometers. Finally, the chlorophyll concentration was calculated using the following equations (Arnon, 1949).

$$\text{Total Chlorophyll} = [(8/02 \cdot A663) + (20/2 \cdot A645)] \cdot V/1000 \cdot W$$

A = Absorbance measured by the spectrophotometer
V = Volume of acetone used (10 mL)
W = Weight of the sample used (0.25 g)

2.7. Statistical analysis

The data were analyzed using SAS software, and Excel was used to create the graphs. The means were compared using Duncan's test.

3. Results

3.1. Growth Parameters

The cultivation of Spathiphyllum in a substrate of peat + perlite + sand resulted in a higher number of leaves in the plant compared to other treatments, while the other growing medium treatments showed a similar level of leaf formation in the plant (Table 3). Using vermicompost at a ratio of 75% by volume in the pot led to a higher number of leaves in the plant compared to the other treatments, whereas in the control treatment without vermicompost, the lowest number of leaves in the plant was recorded (Table 4). The highest number of leaves in the plant was achieved with the interaction of the substrate composed of peat + perlite + sand (equal proportions of substrates at 8.3%) combined with 75% by volume of vermicompost. In contrast, the lowest number of leaves in the plant was observed in the treatments using peat 25% + sand 25% combined with 50% vermicompost, as well as peat 50% + perlite 50% without vermicompost (Table 5).

The leaf length in Spathiphyllum under the treatment of perlite + sand was the shortest compared to other substrates. It appears that the presence of perlite and sand in this treatment played a significant role in rapidly draining water, resulting in stress and reduced leaf length. Conversely, the longest leaf length was recorded in the treatment using peat + perlite + sand, although it did not show a significant difference from the substrates of peat + sand and peat + perlite. This increase can be attributed to the presence of peat in the growing medium (Table 3). The longest leaf length was achieved in the treatment with 75% by volume of vermicompost, while the shortest leaf length was observed in the absence of vermicompost (Table 4). The highest leaf length was obtained from the interaction of the substrate composed of peat + perlite + sand at a ratio of 8.3% combined with 75% vermicompost. However, there was no significant difference when compared to the treatments of peat + perlite + sand at ratios of 16.6% combined with 50% vermicompost and peat + perlite at ratios of 12.5% combined with 75% vermicompost. The shortest leaf length was recorded in the treatment of perlite 50% + sand 50% without vermicompost (Table 5).

The highest number of spathe per plant was obtained in the treatment using the substrates of peat + perlite + sand. In contrast, fewer spathe were formed in the treatments of perlite + sand and peat + sand (Table 3). The application of vermicompost at a ratio of 75% by volume had a significant impact on the formation of spathe per plant, while the lowest number of spathe was observed in the control treatment without vermicompost (Table 4). The largest spathe lengths were recorded in the treatments of peat + perlite + sand and peat + sand, respectively. In contrast, the shortest spathe length was obtained in the treatment of perlite + sand (Table 3). The length of the spathe showed a significant increase with the application of 75% vermicompost by volume, while there was little growth in the treatment without vermicompost (Table 4). The highest spathe length was obtained from the interaction of the substrates composed of peat + perlite + sand (at equal ratios of 8.3%) combined with 75% vermicompost. The lowest spathe length was recorded in the treatment of perlite + sand (50% + 50%) without vermicompost (Table 5). With the increase in the level of vermicompost usage, the width of the spathe in Spathiphyllum also increased, such that the highest spathe width was recorded in the treatment with 75% vermicompost. In contrast, the lowest spathe widths were observed in the treatments without vermicompost and with 25% vermicompost, respectively (Table 4). The application of substrates composed of peat + perlite + sand (at a ratio of 16.6%) combined with 50% vermicompost, as well as peat + perlite (at a ratio of 25%) combined with 50% vermicompost, resulted in the greatest spathe width. These treatments did not show a significant difference compared to the treatment of peat + perlite + sand (at a ratio of 8.3%) combined with 75% vermicompost. The smallest spathe width was observed in the treatments of perlite + sand and peat + sand without the use of vermicompost (Table 5).

Table 3. Comparison of Mean Simple Effects of Substrate on Some Growth Traits in Spathiphyllum

Treatments	Number of Plant Leaves (no./plant)	Leaf Length (cm)	Leaf Width (cm)	Number of spathe (no./plant)	spathe Width (cm)	spathe Length (cm)
Perlite + Sand	4.62b	14.87b	5.26b	1.66b	2.96a	5.95b
Peat + Sand	4.75b	17.03a	5.36b	1.67b	3.04a	6.63a
Peat + Perlite	5.31b	18.05a	5.31b	1.78ab	3.31a	6.43ab
Peat + Perlite + Sand	6.68a	18.34a	6.37a	1.93a	3.40a	6.96a

* Identical letters in the columns indicate no significant difference at the 5% statistical significance level based on Duncan's test.

Table 4. Comparison of Mean Simple Effects of Vermicompost on Some Growth Traits in Spathiphyllum

Treatments	Number of Plant Leaves (no./plant)	Leaf Length (cm)	Leaf Width (cm)	Number of spathe (no./plant)	spathe Width (cm)	spathe Length (cm)
Vermicompost 0%	4.43b	16.15b	5.12a	1.61c	2.59c	5.48c
Vermicompost 25%	5.12b	16.62ab	5.68a	1.68bc	2.89c	6.36b
Vermicompost 50%	5.43ab	17.48ab	5.45a	1.81ab	3.40b	6.81ab
Vermicompost 75%	6.37a	18.03a	6.05a	1.95a	3.84a	7.34a

* Identical letters in the columns indicate no significant difference at the 5% statistical significance level based on Duncan's test.

Table 5. Comparison of Mean Interaction Effects of Substrate and Vermicompost on Some growth Traits in Spathiphyllum

Treatments	Number of Plant Leaves (no./plant)	Leaf Length (cm)	Leaf Width (cm)	Number of spathe (no./plant)	spathe Width (cm)	spathe Length (cm)
Perlite 50% + Sand 50% + Vermicompost 0%	4.00d	13.25d	4.87a	1.61a	2.37e	4.62f
Perlite 37.5% + Sand 37.5% + Vermicompost 25%	4.50d	14.25cd	5.25a	1.65a	2.87d	6.20d
Perlite 25% + Sand 25% + Vermicompost 50%	4.75d	15.25c	5.57a	1.70a	3.00c	6.25d
Perlite 12.5% + Sand 12.5% + Vermicompost 75%	5.25c	16.75b	5.37a	1.70a	3.62b	6.75c
Peat 50% + Sand 50% + Vermicompost 0%	4.50d	16.75b	5.25a	1.60a	2.37e	6.17d
Peat 37.5% + Sand 37.5% + Vermicompost 25%	5.50c	17.25b	5.50a	1.60a	2.81d	6.37cd
Peat 25% + Sand 25% + Vermicompost 50%	3.75e	17.75b	5.00a	1.70a	3.25c	6.87c
Peat 12.5% + Sand 12.5% + Vermicompost 75%	5.25c	16.37bc	5.70a	1.80a	3.75b	7.12b
Peat 50% + Perlite 50% + Vermicompost 0%	3.75e	17.75b	4.62a	1.64a	2.75d	5.37e
Peat 37.5% + Perlite 37.5% + Vermicompost 25%	4.75d	17.50b	5.37a	1.60a	3.12c	6.00d
Peat 25% + Perlite 25% + Vermicompost 50%	6.50b	17.70b	5.25a	1.88a	3.25c	6.75c
Peat 12.5% + Perlite 12.5% + Vermicompost 75%	6.25b	19.25a	6.00a	1.99a	4.12a	7.62a
Peat 33.3% + Perlite 33.3% + Sand 33.3% + Vermi 0%	5.50c	16.87bc	5.75a	1.60a	2.87d	5.75e
Peat 25% + Perlite 25% + Sand 25% + Vermicompost 25%	5.75c	17.50b	6.62a	1.88a	2.75d	6.87c
Peat 16.6% + Perlite 16.6% + Sand 16.6% + Vermicompost 50%	6.75b	19.25a	6.00a	1.96a	4.12a	7.37ab
Peat 8.3% + Perlite 8.3% + Sand 8.3% + Vermicompost 75%	8.75a	19.75a	7.12a	2.29a	3.87a	7.87a

* Identical letters in the columns indicate no significant difference at the 5% statistical significance level based on Duncan's test

Table 6. Comparison of the average simple effects of substrates on some growth traits, Chlorophyll, leaf Nitrogen and Iron in Spathiphyllum.

Treatments	Number of offshoots Formed (no.)	Number of Leaves per offshoots (no.)	Fresh Weight of offshoots ($g.plant^{-1}$)	Dry Weight of offshoots ($g.plant^{-1}$)	Number of Roots per offshoots (no.)	Leaf Chlorophyll ($mg.Kg^{-1}$ FM)	Leaf Nitrogen (% DM)	Leaf Iron ($mg.Kg^{-1}$ DM)
Perlite + Sand	2.09a	1.93a	32.6c	2.65d	2.18c	57.21b	1.67c	72.75c
Peat + Sand	2.13a	2.02a	33.0c	4.17c	3.00b	61.40a	1.81b	80.12b
Peat + Perlite	2.10a	2.13a	36.2b	4.76b	3.25b	61.89a	2.08a	80.62b
Peat + Perlite + Sand	2.17a	2.16a	40.3a	5.59a	4.21a	62.78a	2.12a	88.87a

* Identical letters in the columns indicate no significant difference at the 5% statistical probability level based on Duncan's test.

Table 7. Comparison of the average simple effects of vermicompost on some growth traits, Chlorophyll, leaf Nitrogen and Iron in Spathiphyllum.

Treatments	Number of offshoots Formed (no.)	Number of Leaves per offshoots (no.)	Fresh Weight of offshoots ($g.plant^{-1}$)	Dry Weight of offshoots ($g.plant^{-1}$)	Number of Roots per offshoots (no.)	Leaf Chlorophyll ($mg.Kg^{-1}$ FM)	Leaf Nitrogen (% DM)	Leaf Iron ($mg.Kg^{-1}$ DM)
Vermicompost 0%	1.81b	1.83b	24.58d	3.18d	2.31c	47.95d	1.64c	72.68c
Vermicompost 25%	1.96b	1.91b	30.63c	3.94c	3.25b	58.31c	1.89b	73.06c
Vermicompost 50%	2.26a	2.19ab	44.38a	5.14a	3.25b	64.91b	2.05a	85.25b
Vermicompost 75%	2.46a	2.30a	42.50b	4.90b	3.84a	72.10a	2.10a	91.37a

* Identical letters in the columns indicate no significant difference at the 5% statistical probability level based on Duncan's test.

Table 8. Comparison of the average interactive effects of growing substrate and vermicompost on some growth traits, Chlorophyll, leaf Nitrogen and Iron in Spathiphyllum.

Treatments	Number of offshoots Formed (no.)	Number of Leaves per offshoots (no.)	Fresh Weight of offshoots ($g.plant^{-1}$)	Dry Weight of offshoots ($g.plant^{-1}$)	Number of Roots per offshoots (no.)	Leaf Chlorophyll ($mg.Kg^{-1}$ FM)	Leaf Nitrogen (% DM)	Leaf Iron ($mg.Kg^{-1}$ DM)
Perlite 50% + Sand 50% + Vermicompost 0%	1.78a	1.70a	22.25f	2.68e	1.25e	44.35h	1.47b	67.25h
Perlite 37.5% + Sand 37.5% + Vermicompost 25%	2.03a	1.80a	23.92f	2.65e	1.75e	54.62f	1.77ab	70.00f
Perlite 25% + Sand 25% + Vermicompost 50%	2.03a	2.07a	42.25c	2.65e	2.50d	66.37c	1.67ab	73.25f
Perlite 12.5% + Sand 12.5% + Vermicompost 75%	2.52a	2.13a	42.12c	2.65e	3.25c	63.52d	1.76ab	80.50d
Peat 50% + Sand 50% + Vermicompost 0%	1.88a	1.78a	26.00e	3.29d	3.00c	49.65g	1.51ab	70.00f
Peat 37.5% + Sand 37.5% + Vermicompost 25%	1.88a	1.88a	28.37e	3.59c	3.50c	62.12d	1.68ab	72.00g
Peat 25% + Sand 25% + Vermicompost 50%	2.36a	2.13a	42.47c	5.37b	2.50d	61.55d	2.11a	81.25d
Peat 12.5% + Sand 12.5% + Vermicompost 75%	2.39a	2.28a	35.05d	4.43c	3.00c	72.27b	1.96ab	97.25b
Peat 50% + Perlite 50% + Vermicompost 0%	1.88a	1.94a	23.67f	3.11d	2.00d	45.05h	1.81ab	75.50ef
Peat 37.5% + Perlite 37.5% + Vermicompost 25%	1.88a	1.99a	27.20e	3.59d	3.25c	58.15e	1.98ab	71.25f
Peat 25% + Perlite 25% + Vermicompost 50%	2.29a	2.21a	46.62ab	6.13ab	3.75c	67.27c	2.17a	88.50c
Peat 12.5% + Perlite 12.5% + Vermicompost 75%	2.34a	2.36a	47.20a	6.21a	4.00b	77.00a	2.36a	87.25c
Peat 33.3% + Perlite 33.3% + Sand 33.3% + Vermicompost 0%	1.70a	1.88a	26.40e	3.66d	3.00c	52.75fg	1.78ab	78.00e
Peat 25% + Perlite 25% + Sand 25% + Vermicompost 25%	2.03a	1.99a	42.92c	5.96b	4.50b	58.37e	2.15a	79.00de
Peat 16.6% + Perlite 16.6% + Sand 16.6% + Vermicompost 50%	2.34a	2.34a	46.17ab	6.41a	4.25b	64.37cd	2.24a	98.00ab
Peat 8.3% + Perlite 8.3% + Sand 8.3% + Vermicompost 75%	2.60a	2.43a	45.65b	6.34a	5.12a	75.62a	2.30a	100.50a

* Identical letters in the columns indicate no significant difference at the 5% statistical probability level based on Duncan's test.

As the amount of vermicompost in the growing substrate for Spathiphyllum increased, the number of offshoots produced also rose. In the treatments with 50% and 75% vermicompost, the highest number of offshoots was observed. In the treatments without vermicompost and with 25% vermicompost, the number of offshoots formed was lower than in the two higher treatments (Table 7). The highest number of leaves per offshoot was achieved with 75% vermicompost by volume of the pot, while in the treatments without vermicompost and with 25% vermicompost, fewer leaves were formed per offshoots (Table 7). The highest fresh weight of offshoots was obtained from the substrate combinations of peat + perlite + sand in equal ratios, while the lowest fresh weight of offshoots was from the substrate of perlite + sand. It seems that this treatment did not have a significant difference compared to the peat + sand treatment (Table 6). The fresh weight of offshoots with 50% vermicompost by volume of the pot was higher than in other treatments, while the control treatment with no vermicompost showed the lowest fresh weight of offshoots (Table 7). Due to the interaction of using the substrate of peat + perlite (in a ratio of 12.5%) combined with 75% vermicompost, the fresh weight of offshoots was greater than in other treatments. The lowest fresh weight of offshoots was obtained in the treatments with perlite + sand (at a ratio of 50%) and without vermicompost, as well as with perlite + sand (at a ratio of 37.5%) combined with 25% vermicompost (Table 8). The highest dry weight of offshoots was achieved with the substrate of peat + perlite + sand, while the lowest dry weight was associated with the treatment of perlite + sand (Table 6). With the application of 50% vermicompost by volume of the pot, the dry weight of offshoots was greater than in other treatments, and the control treatment with no vermicompost showed the lowest dry weight of offshoots (Table 7). The highest dry weight of offshoots was obtained in the treatment by combining the substrate of peat + perlite + sand (in a ratio of 16.6% by volume of the pot) with 50% vermicompost by volume. However, this treatment did not show a significant difference compared to the substrates of peat + perlite + sand (in a ratio of 8.3% by volume) with 75% vermicompost, as well as the substrate of peat + perlite (12.5% by volume) combined with 75% vermicompost. The lowest dry weight of offshoots was observed in the treatments using perlite + sand across all levels of vermicompost, and these treatments did not have significant differences among themselves (Table 8).

The highest number of roots formed in the offshoots was found in the treatment with the substrate of peat + perlite + sand, while the lowest number of roots was associated with the treatment of perlite + sand. It seems that the addition of peat to the growing substrate helps retain moisture and nutrients, leading to better root development (Table 6). The highest number of roots in the offshoots was achieved with the application of 75% vermicompost by volume of the pot, while the lowest number of roots corresponded to the control treatment without vermicompost (Table 7). The use of the substrate combination of peat + perlite + sand (in a ratio of 8.3% by volume of the pot) along with 75% vermicompost had the highest number of roots in the offshoots, while the lowest number of roots was obtained in the treatment with perlite + sand (at 50% volume) and without vermicompost (Table 8).

3.2. Total leaf chlorophyll

The chlorophyll content in the leaves of Spathiphyllum was higher in substrates containing peat compared to those without it. It seems that peat may play an effective role in the absorption of elements like zinc, iron, and magnesium by acidifying the growing substrate, which ultimately enhances leaf greenness (Table 6). Adding 75% vermicompost by volume of the pot to the substrate for Spathiphyllum resulted in the highest leaf chlorophyll content, while the lowest chlorophyll content was found in the treatment without vermicompost. This suggests that vermicompost, due to its nutrient content, plays an important role in enhancing plant greenness (Table 7). The highest leaf chlorophyll content was achieved with the treatment using peat + perlite (at a ratio of 12.5% by volume of the pot) combined with 75% vermicompost. This treatment did not show a significant difference compared to the treatment with 75% vermicompost combined with the substrate of peat + perlite + sand at a ratio of 8.3% by volume. The lowest leaf chlorophyll content was associated with the treatment of perlite + sand (at 50% by volume) without vermicompost (Table 8).

3.3. Leaf Nitrogen

The nitrogen content in the leaves was higher in the treatment with peat + perlite compared to other treatments. The lowest nitrogen content was found in the treatment with perlite + sand (Table 6). In the treatments with 50% and 75% vermicompost by volume of the pot, there was a significant increase in leaf nitrogen, while the lowest nitrogen content was observed in the treatment without vermicompost (Table 7). The highest leaf nitrogen content was achieved with the application of peat + perlite in a ratio of 12.5% by volume of the pot combined with 75% vermicompost. However, this treatment did not show a significant difference compared to some other treatments. The lowest leaf nitrogen content was obtained in the treatment of perlite + sand at a ratio of 50% alone (Table 8).

3.4. Leaf Iron

The highest leaf iron content was obtained in the substrate of peat + perlite + sand, while the lowest leaf iron content was found in the treatment with perlite + sand (Table 6). With the increase of vermicompost in the growing substrate, the leaf iron content in Spathiphyllum also increased. In the treatment with 75% vermicompost by volume of the pot, the iron content rose to 91.37 mg per kg, while the lowest leaf iron content was observed in the treatment without vermicompost (Table 7). Due to the interaction of the substrates peat + perlite + sand at a ratio of 8.3% by volume of the pot combined with 75% vermicompost, the highest leaf iron content was achieved. Conversely, the treatment using perlite + sand at a ratio of 50% by volume of the pot without vermicompost resulted in the lowest leaf iron content (Table 8).

4. Discussion

Albaho *et al*. (2009) examined the effect of three growing substrates on the growth and yield of sweet pepper. Their results indicated that the growing substrate has a significant impact on plant height, number of leaves, chlorophyll index, and overall plant performance. Samiei *et al*. (2005) investigated the potential of replacing peat moss substrates with cellulose waste from date palm trees in the ornamental plant Aglaonema. They found that the growing substrate treatment had a significant effect on growth indices. The highest leaf area, stem length, number of offshoots, and dry weight of aerial and root parts were observed in the substrate of cocopeat, while the lowest values were recorded in sugarcane bagasse. In a study aimed at examining the effects of different growing substrates on the vegetative and reproductive traits of cherry tomatoes, the highest number of nodes, leaves, and fresh and dry weights of aerial parts were found in the treatment of 95% perlite + 5% hydrogel, while the greatest stem length, fresh weight, and dry weight of roots were associated with the treatment of 100% perlite (Yousefian *et al*., 2009). Lee *et al*. (1999) identified perlite and the mixture of perlite + carbonized rice husk as the most important substrates for the hydroponic cultivation of cucumber, among the substrates of perlite, perlite + carbonized rice husk, and pure rice husk. (Çakırer *et al*., 2016; Gol, 1996) reported the highest and lowest yields from peat and rice husk substrates, respectively, and also noted that the growing substrates had little effect on the quality traits of the produce. Esfandiari *et al*. (2009) stated that the growing substrate significantly affects the fruit yield of tomatoes, the number of fruits per plant, and fruit weight, with the highest values for these traits found in enriched zeolite and perlite, while the lowest weight was recorded in perlite alone. Mami and Peyvast (2008) indicated that substrates showed significant differences regarding the number of fruits. Parks *et al*. (2004) noted that the growing substrate does not affect the average weight of cucumbers. Tuzel *et al*. (2001) stated that the combination of peat and perlite yields positive results for the growth and performance of tomatoes. The high porosity of perlite provides optimal aeration for the roots, and the combination of peat with other organic and inorganic substrates enhances performance compared to pure substrates. The water retention capacity and good cation exchange capacity of peat are crucial for improving results. The experimental results indicated that there are significant dual effects between the growing substrate and different salinity levels on all traits.

In an experiment conducted by Premuzic *et al*. (1998) on tomatoes, it was found that fruits from organic substrates exhibited better quantitative and qualitative characteristics compared to those from mineral substrates. They concluded that organic substrates increased calcium levels and reduced iron levels in the fruits. In another study, Mobli *et al*. (2008) compared various growing substrates on the vegetative growth and yield of tomatoes. The treatments included five growing substrates: perlite (100%), wood chips (100%), wood chips (50%) + perlite (50%), wood chips (75%) + zeolite (25%), and perlite (75%) + zeolite (25%). The results showed that the highest yield (in terms of the number of fruits and total weight of harvested fruits) was associated with the perlite + zeolite treatment, while the lowest yield was recorded for the pure wood chip treatment. Additionally, the incorporation of zeolite into wood chips significantly increased the yield compared to the pure wood chip treatment. Mobli *et al*. (2008) conducted a study to investigate the effects of different growing substrates on the vegetative and reproductive growth of bell peppers. The treatments included zeolite (25%), perlite (75%) + zeolite (25%), and wood chips (75%) + zeolite (25%). The results indicated that for all the measured vegetative traits, the highest values were associated with the perlite + zeolite treatment. AI-menace (2008) investigated the growth and flowering of gardenia samples by changing the growing substrate. Four substrates—sand, potting soil, peat moss, and perlite—were used in this experiment. The results showed that the growing substrate plays a significant role in the growth and flowering of this plant. A comparison of the effects indicated that potting soil and perlite in a 1:1 ratio is beneficial for houseplants while potting soil and peat moss in a 1:1 ratio positively influences growth, health, development, and flower production for outdoor plants. Moisture, aeration, and organic matter in the growing substrate are three influential factors in the growth and flowering of gardenia.

Davary *et al.* (2009) conducted an experiment to investigate the effects of irrigation frequency and growing substrate on the yield and some growth parameters of lettuce in soilless cultivation. The experiment included three levels of irrigation in the main plots and three substrates: new perlite, used perlite, and rice bran in the subplots. They reported that there was no significant difference among the studied substrates regarding plant height. However, the used perlite substrate resulted in a reduction in plant height compared to the new perlite. Additionally, significant differences were observed among the substrates concerning yield. The highest and lowest weights were associated with the old perlite substrate at 491.1 g and rice bran at 305 g, respectively. There were also significant differences in dry weight among the different substrates. The old perlite substrate produced the highest dry weight, while the rice bran substrate produced the lowest dry weight.

Bunt (1998) stated that the application of peat in plant cultivation alone often shows signs of nutrient element deficiencies. However, its combination with mineral soils has beneficial effects on plant growth, attributed to the role of peat in the chemical processes affecting the availability and balance of nutrients. Lihong *et al*. (2000) investigated the combined effects of peat moss and copper sulfate on soil and potato plant performance, finding that mixing peat with sandy soils improved physical properties and increased potato yield. White (1985), in a report on various growing media for Petunia, indicated that a strong and well-draining growing medium containing decomposed manure with adequate aeration and drainage is more suitable. Golrang *et al.* (2013) conducted a study on the effect of substrate type and planting networks on the quality traits of Roll grass and reported that color, chlorophyll a, and total chlorophyll content after the first winter frost were significantly higher in the substrate (30% compost + 70% clay) compared to the other substrates. On the other hand, substrates with a higher clay percentage exhibited more uniformity and density of weeds. In terms of color, chlorophyll b, and total chlorophyll, substrates containing compost showed superiority over the other substrates after the first winter frost.

Hamidpour *et al*. (2013) reported that the application of zeolite and vermicompost increased the dry weight of aerial parts, root dry weight, number of flowers, number of leaves, flower diameter, final plant height, and concentrations of total nitrogen, phosphorus, potassium, and calcium in the petunia plants. The highest values for the growth parameters were associated with the 10% vermicompost treatment, which showed a significant difference compared to the control treatment. The lowest values for the growth parameters were related to the control treatment. Mahboub Khamami (2011) reported in a study the effect of vermicompost combined with sawdust in potting media on the nutrition and growth of Dieffenbachia plants. The highest plant height was achieved with 50% Vermicompost of cow manure + sawdust, while 25% Vermicompost of cow manure + sawdust resulted in the largest stem diameter, as well as the highest fresh weight of the stem and leaves, dry weight of the stem and leaves, and fresh root weight. Results from experiments on the ornamental plant Magnolia virginiana showed that the application of 10% vermicompost significantly increased the plant's dry weight (Bachman and Davis, 2000). Hashemi Majd (2010) mentioned that there are various reports regarding the effect of vermicompost on the availability of nutrients elements and their increased usability in the soil. Most of the emphasis has been on the benefits and impact of vermicompost on plant growth. Additionally, compost and vermicompost have similar effects, but since vermicompost contains a higher amount of hummus compounds, its impact on the physical properties of the soil is greater.

Chattopadhyay *et al*. (1992) reported that the application of vermicompost alone led to the absorption of greater amounts of iron, manganese, and zinc by plants. Vermicomposts improve the physical, chemical, and biological properties of the soil. Compared to soils, vermicomposts have lower solutes, higher cation exchange capacity, and greater humic acid content. Various researchers have tested the potential of converting waste materials through earthworms and generally recommend the use of vermicompost in horticulture and agricultural industries (Arancon *et al*., 2005). Safari *et al*. (2009) experimented to evaluate the effects of biological fertilizers, including compost, vermicompost, and sulfur-coated granulated compost, on some important growth characteristics of the ornamental plant pothos in the municipality of Mashhad. He reported that various amounts of fertilizers at ratios of 5%, 10%, 15%, and 20% were tested, with the results showing that 15% vermicompost had significant positive effects compared to the other ratios and fertilizers. Azizi *et al*. (2008) also reported that the application of vermicompost in the medicinal plant chamomile resulted in increased growth indices, followed by enhanced nutrient element uptake in this plant.

Conclusions

Considering the importance of cultivating Spathiphyllum as a houseplant and the significance of determining the type of cultural substrate and its nutrition using organic fertilizers, the results obtained from the experiment showed that the interactive use impact of cultural substrate and vermicompost on important traits such as the number of leaves in the plant, length and width of the spathes, fresh and dry weight of the offshoots, and the amount of chlorophyll, nitrogen, and iron in the leaves showed significant differences among the applied treatments. Such that the combination of peat + perlite + sand (in the ratios of 8.3% by volume of the pot) with 75% vermicompost had the highest values for leaf length, spathe length, number of roots in the offshoots, leaf chlorophyll content, leaf nitrogen, and leaf iron, demonstrating 20 to 30% greater effects compared to all other treatments. In contrast, the treatment with 50% perlite + 50% sand without vermicompost had the lowest values for all mentioned traits. The dry weight of the offshoots and the width of the spathes were higher in the treatment of peat + perlite + sand (16.6%) and 50% vermicompost compared to all treatments. Since the peat + perlite + sand 8.3% combined with 75% vermicompost had a significant impact on most traits, this treatment can be recommended as the most suitable cultural substrate and nutritional option for Spathiphyllum.

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