Azizi Yeganeh *et al. BMC Plant Biology* (2024) 24:149
https://doi.org/10.1186/s12870-024-04807-0

BMC Plant Biology

RESEARCH Open Access

Vermicompost as an alternative substrate to peat moss for strawberry (*Fragaria ananassa*) in soilless culture

Mahsa Azizi Yeganeh[1], Ali Asghar Shahabi[2*], Ali Ebadi[3] and Vahid Abdoosi[1]

Abstract

Background Consecutive droughts and quantitative and qualitative reduction of surface and underground water resources have caused an increase in greenhouse and hydroponic cultivation for most garden crops, including strawberries, in Iran. On the other hand, most of the inputs of greenhouse crops in Iran are imported. To possibility of replacing vermicompost with peat moss under hydroponic cultivation, an experiment was done in a split plot based on randomized complete blocks design in three replications in Isfahan (Iran) Agricultural and Natural Resources Research Center in 2019. The main treatment was substrate at four levels included different levels of vermicompost (30 and 50%) and peat moss (30 and 50%) in combination with perlite and sub-treatment were Selva and Camarosa cultivars.

Results The results showed that Camarosa cultivar and Selva cultivar in (perlite/ peat moss 50:50) and Selva cultivar in (perlite / vermicompost 70:30) had maximum yield.

Leaf number and chlorophyll index were maximum in Camarosa cultivar in peat moss substrates. Strawberry cultivars had the highest root fresh weight, the content of vitamin C and total soluble solids (TSS) in substrates containing vermicompost. Camarosa cultivar in (perlite / peat moss50:50) and Selva cultivar in (perlite /vermicompost 50:50) had maximum root dry weight. Also, the highest number of inflorescences was related to substrates containing peat moss and (perlite /vermicompost 70:30). Maximum amount of fresh and dry weight of shoots were observed in (perlite/ peat moss70:30). Selva cultivar had more inflorescences (16.5%) than Camarosa cultivar and Camarosa cultivar produced more fresh and dry weight of shoots (16.5%, 23.01%) than Selva cultivar.

Conclusion Expriment results highlighted the importance of considering both main and sub-treatments in agricultural research, as they interacted to influence various growth and yield parameters. 50% vermicompost treatment combined with perlite had a positive impact on plant growth and in quality index such as vitamin C content and TSS was highest. while the choice of cultivar affected different aspects of plant development. Selva cultivar was known to be more tolerant to salinity caused by vermicompost. Vermicompost is local and more economical, also salt resistant cultivars are recommended in a controlled (30%) amount of vermicompost.

Keywords Camarosa, Cultivar, Hydroponic, Selva, Vitamin C

*Correspondence:
Ali Asghar Shahabi
aliasgharshahabi45@gmail.com
Full list of author information is available at the end of the article

© The Author(s) 2024. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

Background

The cultivation of is an important agricultural practice worldwide. Farmers and researchers constantly seek innovative techniques to enhance crop productivity and quality. One such approach is the use of organic amendments like vermicompost and peat moss, which have demonstrated positive effects on plant growth and yield. Additionally, the selection of appropriate strawberry cultivars is crucial for optimizing outcomes. Strawberry (*Fragaria* × *ananassa* Duch.) is one of the most popular soft berry fruits [45]. Now, they are as a matter of functional food with numerous health benefits such as source of natural antioxidants, such as carotenoids, phenolics, vitamins, anthocyanins, and flavonoids [15, 31].

Food production by soilless culture method has become more attractive than traditional soil culture due to its advantages, such improved quality control over the growth environment and reduce of uncertainties related to soil, water, and nutrient availability [31].

Peat moss itself is a type of organic material derived from partially decomposed plant matter found in peat bogs. It is widely used in horticulture and gardening due to its excellent water-holding capacity, aeration properties, low pH, low bulk density, low nutrient content, and useful cation exchange capacity and ability to improve soil structure [11].

While peat moss has been widely used, there is growing concern about the sustainability of its extraction from peat bogs. As an alternative, compost-based substrates, and other organic materials are being explored as substitutes for peat moss in horticulture [32]. Vermicompost is one of domestically produced organic substrates that is important in agriculture sector, especially for production of greenhouse products. In recent years, use of vermicompost in horticulture as a high-use growing substrate has increased [15].

Organic composts exhibit qualities similar to peat in terms of porosity, aeration, and water holding capacity. They are renewable resources that are produced locally [21, 33].

Vermicompost is used as a suitable alternative to chemical fertilizers in various crops. Vermicomposting is a non-thermophilic process that converts organic waste materials into valuable fertilizer through the combination of worms and mesophilic microbes [33]. Vermicompost contain substances that control plant growth, such as humic acids, auxins, gibberellins, and cytokinins which control a variety of processes related to plant growth and yield [10].

There are some reports in the previous study on utilization, vermicompost in cultivation. The highest yield (408.04 g plant-1), fruit weight (18.5 g), Tss (8.33%), pH (3.95%) and total sugar ((Glucose + Fructose) mg 100 g − 1) in strawberry (*Fragaria vesca* L.) plants were obtained with the use of vermicompost (250 kg da − 1) compared to the control group and the use of chemical fertilizers [34].

Khatiwada [14] reported that shoot, root, and leaf growth characteristics were significantly affected by the application of vermicompost in strawberry (*Monterey cultivar*) plant.

In an experiment conducted by [39], the flower initiation was recorded at vermicompost (50%) also the highest fruit yield and highest soluble solid content at the time of harvest was recorded with treatment vermicompost (100%) and (50%).

In other experiment application of 100% vermicompost with other substrate was found most effective in vegetative attributes as well as yield per hectare of Strawberry fruit [41].

In an experiment conducted on strawberries, vermicompost in in a relatively low dose (equivalent to 170 kg N/ha) had a positive effect on the yield. Also, the quality of strawberry fruit such as total soluble solids, total anthocyanins, antioxidant activity of the fruit, and a lower concentration of total acid improved significantly [10].

The purpose of this study is to replace vermicompost instead of peat moss in Iran. Due to economic sanctions, using vermicompost in Iran can indeed be more economical than peat moss for several reasons: Local production, Lower cost, Sustainable waste management and Soil health benefits. In addition to being more budget-friendly, vermicompost also offers several benefits, such as being a sustainable and organic source of nutrients, improving soil structure and promoting beneficial microbial activity. These advantages contribute to enhanced plant growth and yield, making vermicompost a favorable choice for many farmers and growers.

Results

Yield

Yield of the two cultivars of strawberry was significantly affected by the substrate and interaction between substrate and cultivars (Table 1). Higher values of yield were recorded on Camarosa cultivar in the substrate with 50% perlite/ 50% peat moss (S1C2:39.31 gr) and on Selva cultivar with no significant difference in 50% perlite / 50% peat moss and 70% perlite /30% vermicompost (S1C1:34.26gr and S4C1:33.53gr) (Fig. 1).

The number of leaves

Leave numbers of strawberry were significantly affected by the substrate and interaction between substrate and cultivars (Table 1). Maximum number of leaves were recorded in Camarosa cultivar grown with 50%

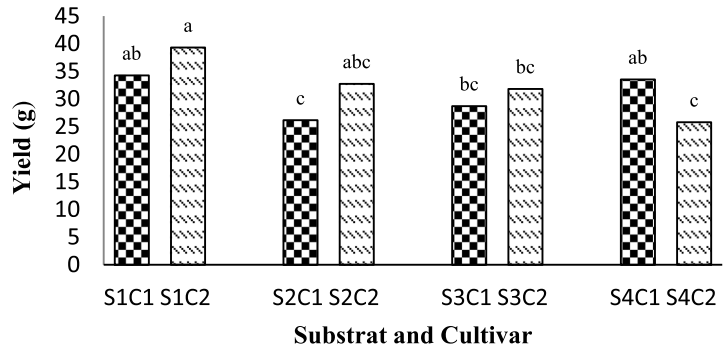
Content courtesy of Springer Nature, terms of use apply. Rights reserved.

Table 1 Analysis of variance substrate and cultivar on some physiological and biochemical traits of Selva and And Camarosa cultivar

Source of variance	Df	Mean sum of squares									
		Yield	Leaf	Inflorescence	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight	Chlorophyll index	Total Soluble Solid	Vitamin C
SUBSTRATR (S)	3	74.16**	1.39**	0.13*	114.92**	12.79**	3.23^{ns}	0.48^{ns}	14.34**	0.57**	104.99**
Error	6	7.97	0.19	0.02	6.51	0.66	13.19	1.31	1.39	0.06	80.8
Cultivar (C)	1	18.28^{ns}	1.17^{ns}	0.34**	92.53*	17.96*	8.21^{ns}	0.008^{ns}	14.95**	0.47**	277.44**
S × C	3	62.89*	3.01**	0.08^{ns}	23.47^{ns}	1.94^{ns}	7.95*	1.92*	3.59	0.18*	55.28*
Error	8	14.3	0.49	0.03	13.31	2.61	1.73	0.33	0.86	0.04	14.62
Coefficient of variation (%)		11.99	8.09	10.97	14.50	19.16	17.46	15.01	1.97	3.87	6.07

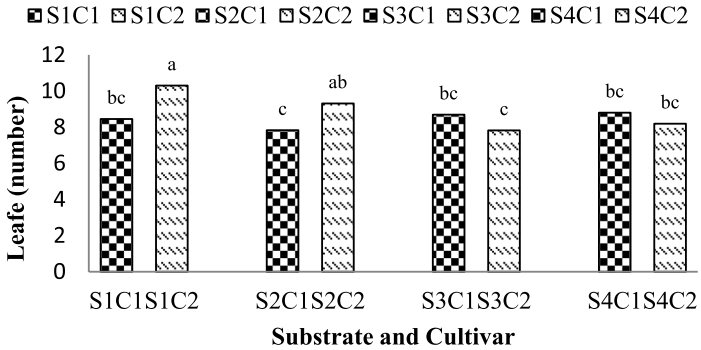
ns * and ** indicates non-significant, significant at $P \leq 0.05$ and $P \leq 0.01$, respectively

Content courtesy of Springer Nature, terms of use apply. Rights reserved.



S_1:50% perlite / 50% peat moss, S_2: 70% perlite / 30% peat moss, S_3:50% perlite / 50% vermicompost and S_4:70% perlite /30% vermicompo C_1: Selva and C_2: Camarosa. Similar letters are no significant difference.

Fig. 1 Yield of Selva and Camarosa in Vermicompost and Peat moss combined with Perlite



S_1:50% perlite / 50% peat moss, S_2: 70% perlite / 30% peat moss, S_3:50% perlite / 50% vermicompost and S_4:70% perlite /30% vermicompost C_1: Selva and C_2: Camarosa. Similar letters are no significant difference.

Fig. 2 Leaf number of Selva and Camarosa in Vermicompost and Peat moss combined with Perlite

perlite/50% peat moss and 70% perlite/30% peat moss (S1C2: 10.3 and S2C2:9.31) (Fig. 2).

Inflorescences

Inflorescences of strawberry significantly influenced by substrates and cultivars (Table 1). The highest number of inflorescences was related to substrates containing peat moss (S1 and S2) and 70% perlite / 30% vermicompost (S4) (Table 2). Selva cultivar produced more inflorescences (16.5%) than Camarosa (Table 2).

Fresh and dry shoot of weight

Fresh and dry shoot of weight significantly influenced by substrates and cultivars (Table 1). Maximum amount of fresh and dry weight of shoots were observed in 70% perlite/30% peat moss (S2) (Table 2). Camarosa cultivar produced more fresh and dry weight of shoots (16.5%, 23.01%) than Selva cultivar (Table 2).

Table 2 Inflorescence, shoot fresh weight and shoot dry weight of Selva and Camarosa as affected by substrate and cultivar

Substrate	Inflorescence	Shoot fresh weight(g)	Shoot dry weight(g)
50% perlite / 50% peat moss (S1)	1.75^{a}	8.85^{b}	2.92^{b}
70% perlite / 30% peat moss (S2)	1.61^{ab}	10.12^{a}	3.40^{a}
50% perlite/ 50% vermicompost (S3)	1.40^{b}	6.69^{c}	2.22^{c}
70% perlite / 30% vermicompost (S4)	1.51^{ab}	7.86^{bc}	2.72^{b}
Cultivar			
Selva (C1)	1.69^{a}	7.73^{b}	2.52^{b}
Camarosa (C2)	1.45^{b}	9.04^{a}	3.10^{a}

Similar letters indicate no significant difference

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

Fresh and dry root weight

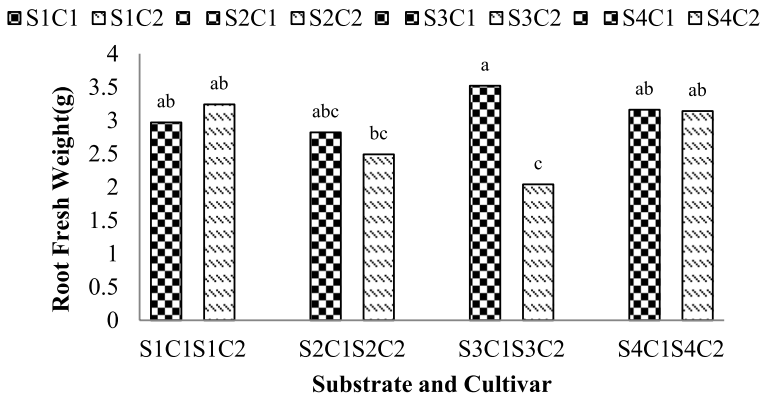
Fresh and dry root of weight were significantly affected by interaction between substrate and cultivars (Table 1). Regarding to the measurement of root weight, higher fresh weight of roots was measured in Selva grown with 50% perlite/50% vermicompost (S3C1:3.52 gr) (Fig. 3), dry weight of roots in Camarosa cultivar grown with 50% perlite/50% peat moss and dry weight of roots in Selva cultivar grown with 50% perlite/50% vermicompost (S1C2:1.4 and S3C1:1.33) with no significant differences were recorded (Fig. 4).

Chlorophyll

Chlorophyll content significantly affected by substrate and cultivar and interaction between substrate and cultivars (Table 1). Levels of chlorophylls observed in Camarosa cultivar was higher in substrates containing peat moss (S1C2: 49.79 and S2C2:49.54) (Fig. 5). Both cultivars of strawberries grown in substrates with vermicompost did not have chlorophyll index as much as cultivars grown in substrate with peat moss (Fig. 5).

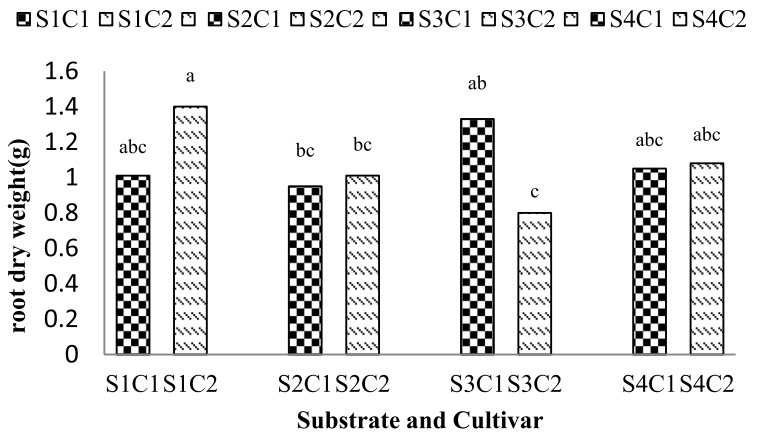
Total Soluble Solid (TSS)

Total soluble solid showed significant differences between cultivars grown in substrate with peat moss and vermicompost (Table 1). Selva cultivar had the highest



S_1:50% perlite / 50% peat moss, $S_{2:}$ 70% perlite / 30% peat moss, $S_{3:}$50% perlite / 50% vermicompost and $S_{4:}$70% perlite /30% vermicompost. C_1: Selva and C_2: Camarosa. Similar letters are no significant difference.

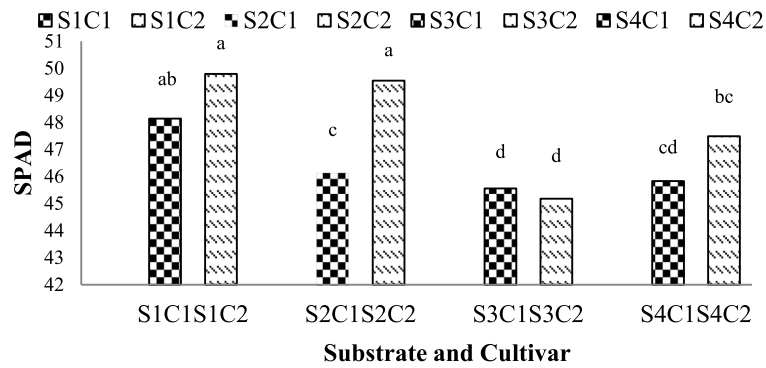
Fig. 3 Root fresh weight of Selva and Camarosa in Vermicompost and Peat moss combined with Perlite



S_1:50% perlite / 50% peat moss, $S_{2:}$ 70% perlite / 30% peat moss, $S_{3:}$50% perlite / 50% vermicompost and $S_{4:}$70% perlite /30% vermicompos C_1: Selva and C_2: Camarosa. Similar letters are no significant difference.

Fig. 4 Root dry weight of Selva and Camarosa in Vermicompost and Peat moss combined with Perlite

Content courtesy of Springer Nature, terms of use apply. Rights reserved.



S_1:50% perlite / 50% peat moss, S_2: 70% perlite / 30% peat moss,
S_3:50% perlite / 50% vermicompost and S_4:70% perlite /30% vermicompost.
C_1: Selva and C_2: Camarosa. Similar letters are no significant difference.

Fig. 5 Chlorophyll index of Selva and Camarosa in Vermicompost and Peat moss combined with Perlite

amount of total soluble solids in 50% perlite/50% vermicompost (S3C1: 6.2 Brix) (Fig. 6).

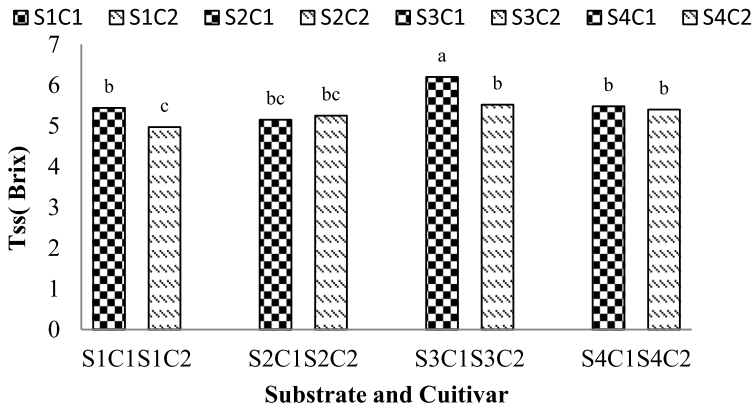
Vitamin C contents

Vitamin C contents of strawberries were significantly affected by the substrate, cultivars and interaction between them used (Table 1). An increase of vitamin C content was measured in Camarosa cultivar grown in the substrate based in vermicompost (S3C2:69.21mg/l and S4C2:71.52 mg/l) (Fig. 7).

Discussion

Yield

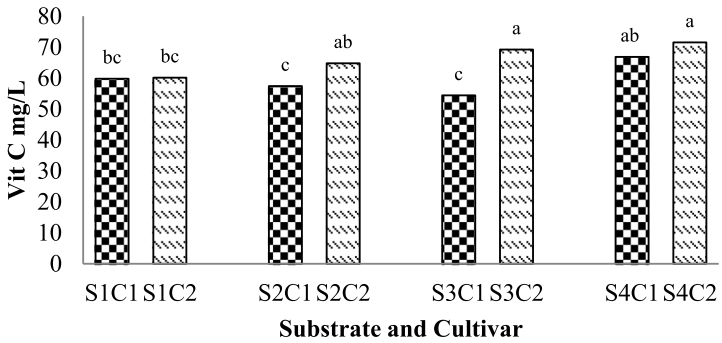
According to the result Selva cultivar had the highest yield in (perlite / peat moss 50:50) and (perlite / vermicompost 70:30) and the results in these two substrates were not significantly different from each other. This result showed that the substrate containing 30% vermicompost can be as effective as peat moss in increasing yield. vermicompost in low doses has a similar yield to peat moss because low doses of vermicompost contain lower levels of salts. High salt content in soil can negatively affect plant growth and yield. Increased yield by vermicompost in the results of research related to Marigold(*Tagetes*) [30], Eggplant (*Solanum melongena*) [25], Cucumber (*Cucumis sativus*)[9], Okra(*Abelmoschus esculentus*) [6], Potato (*Solanum tuberosum*) [17] and Strawberry (*Fragaria ananassa*) [40] Is also visible. The positive role of vermicompost in this case can be explained by the fact that the presence of N, P, K in



S_1:50% perlite / 50% peat moss, S_2: 70% perlite / 30% peat moss,
S_3:50% perlite / 50% vermicompost and S_4:70% perlite /30% vermicompost
C_1: Selva and C_2: Camarosa. Similar letters are no significant difference

Fig. 6 Total soluble solid of Selva and Camarosa in Vermicompost and Peat moss combined with Perlite

Content courtesy of Springer Nature, terms of use apply. Rights reserved.



S_1:50% perlite / 50% peat moss, S_2: 70% perlite / 30% peat moss,
S_3:50% perlite / 50% vermicompost and S_4:70% perlite /30% vermicompost
C_1: Selva and C_2: Camarosa. Similar letters are no significant difference

Fig. 7 Vitamin C contents of Selva and Camarosa in Vermicompost and Peat moss combined with Perlite

vermicompost, as well as micro and essential elements in it, was effective in increasing fruit weight and subsequent increase in yield, [23] are coordinated. Also, vermicompost reduces the accumulation of nutrients and increases the uptake by the plant by the coordination and balance that it creates between the release of nutrients and absorption, and consequently the plant yield increases [47].

The number of leaves

Whereas the substrates with vermicompost had not the highest number of leaves, leaf production, in addition to depending on the type of cultivar, is affected by factors such as light, nutrients and growth factors. Peat moss can improve the cohesion of the root system and substrate [20], also the presence of growth hormones such as auxin in it [27] and creating a fine texture of the soil that increases water holding capacity [37], it can cause vegetative growth including the growth of leaves. In this trait, vermicompost could not produce as many leaves as peat moss. This may be because peat moss often improves retention, which is very effective in vegetative growth while vermicompost increases the fertility of the growing environment [3].

Inflorescences

Although the plants grown in the peat moss substrates had more inflorescences, but the substrate with 30% vermicompost (S4) was able to produce the same number of flowers as the substrate with 30% peat moss (S2), without any significant difference between the two substrates (Table 2). Vermicompost, which is the product of composting organic materials using earthworms, has been shown to have positive effects on plant growth, including the improvement of inflorescences (flowers and flower clusters) in various plant species.The results of other researchers can be seen in positive effect of vermicompost in increasing the number of flowers in Marigold [30], Lilies (*Lilium*) [18] and Strawberry [7]. Increasing the level of nitrogen [10] and microbial activity following the addition of vermicompost leads to root expansion and greater uptake of nutrients, water and photosynthesis and ultimately leads to better flowers and shoots [12]. In addition, the presence of substances that affect plant growth, such as plant growth hormones and humic acids, has been suggested as a possible factor that helps increase plant growth [29]. The higher inflorescence production of Selva cultivar in vermicompost substrate could be attributed to several factors. Selva cultivar may have genetic characteristics that make it more responsive to the nutrients and conditions provided by vermicompost, resulting in increased inflorescence production compared to Camarosa cultivar or they might be better adapted to the specific growing conditions where they are cultivated. Additionally, the cultivation practices used for Selva cultivars might be optimized to encourage more inflorescence development compared to Camarosa cultivars. The type of cultivar also affected the number of inflorescences per plant, which [5] obtained a similar result.

Fresh and dry shoot of weight

Fresh and dry shoot weight depends on plant species [3]. The plants grown in the vermicompost substrate did not have the highest fresh and dry weight of shoot. But fresh and dry weight of shoot in 50% perlite / 50% peat moss (S1) and 70% perlite / 30% vermicompost (S4) were without significant differences from each other (Table 2). Improving the growth of the branches may be related to improving the water condition of the branches. Loss of transpiration of leaves and water uptake by roots directly affects the water status of the branches. Peat moss has

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

high porosity and higher water holding capacity than vermicompost which provides permanent and accessible moisture for plant and stimulates the growth of shoots [14]. In addition, peat contains different types of auxin (Indole acetic acid) hormones that cause vegetative growth in plants [27]. In 70% perlite /30% vermicompost (S4), when increasing perlite and increasing porosity and ventilation, shoot growth increased somewhat (Table 2). Stem weight with application of vermicompost can be seen in Lilium [22] and Pak Choi [28].

Fresh and dry root weight

The increase in fresh and dry weight of roots can be attributed to several factors that may have positively influenced root growth and development. Root growth is a complex process influenced by various environmental, genetic, and physiological factors. The fresh and dry weight of the roots depends on the plant species [3]. The Selva cultivar might possess specific genetic traits that promote robust root growth. This would allow the plant to take up essential nutrients in vermicompost more effectively from the growing medium, leading to healthier and heavier roots. Vermicompost can play a significant role in increasing the fresh and dry weight of roots in plants. Increasing the absorption of essential macro and micro nutrients in vermicompost leads to improved root growth. When vermicompost is applied, it releases these nutrients gradually, providing a steady and balanced supply of nutrients to the plants. This nutrient availability promotes healthy root growth and encourages the development of a robust root system. In addition, the large amount of humic acid and the presence of auxin in vermicompost leads to the proliferation and elongation of secondary roots and increase the total length of the root surface [15, 29]. Vermicompost also improves the condition of the substrate and its water holding capacity by affecting the physical, chemical and biological properties of the substrate [16], which is effective in root expansion. The improved substrate structure allows roots to penetrate the substrate more easily and encourages lateral root development. Significant activity of microorganisms in vermicompost that convert ammonium nitrogen to nitrate can also increase root diameter and increase fresh and dry weight of roots [35]. Also, these microbes contribute to the development of a healthy rhizosphere (root zone) by promoting nutrient cycling and improving nutrient uptake by roots. Vermicompost has been previously shown to result in increase weight of root in pea (*Pisum sativum*) [13], dry weight of root in pepper (*Capsicum*) and strawberry [7], tomato (*Solanum lycopersicum*) and cucumber [8] and fresh weight of root in *Lilium longiflorum* [22].

Chlorophyll

The chlorophyll index in plants refers to the relative amount of chlorophyll present in the leaves, which is an indicator of photosynthetic activity and plant health. While both peat moss and vermicompost can be used as substrate to enhance plant growth, there are specific differences in their effects on the chlorophyll index.

when comparing the chlorophyll index in peat moss and vermicompost directly, vermicompost is more likely to result in a higher chlorophyll index due to its nutrient content, particularly nitrogen [29], but in this experiment, vermicompost could not have maximum chlorophyll index. Peat moss / perlite ratio (1: 1) is used as a standard substrate in most culture systems [2]. Therefore, the high chlorophyll content in strawberries grown in peat moss can be attributed to properties such as low pH, good texture and good water retention ability that is effective in providing high nutrient status and creating suitable conditions for growth [37].

The pH of the growing medium can influence nutrient availability to plants. Peat moss is known to have a slightly acidic pH [37], which can enhance the availability of certain nutrients like iron, which is essential for chlorophyll synthesis. Also, peat moss might have been provided a more suitable nutrient balance for chlorophyll synthesis in this experiment.

Total Soluble Solid (TSS)

Total soluble solid and total acidity are the main sensory and taste factors in strawberry fruits. Fruit brix values depend on variety, cultivation system and harvesting stage [44]. Different plant cultivars have varying genetic traits that can affect their ability to accumulate and transport sugars and other soluble solids within their tissues. The Selva cultivar may have genetic characteristics that promote higher sugar accumulation, leading to increased total soluble solids.

The increase in TSS and total sugar in strawberries is associated with the rapid conversion of starch and pectin metabolites to soluble compounds and the rapid translocation of sugars from the leaves (source) to the growing fruit (sink) [16]. Vermicompost is a nutrient-rich organic fertilizer, and its application can influence the availability of nutrients to plants which can help to increase and synthesize sugar in fruits [23]. Vermicompost contains beneficial microorganisms that can enhance nutrient uptake and nutrient use efficiency in plants [35]. These microorganisms may have positively influenced the Selva cultivar's ability to absorb and utilize nutrients, leading to higher total soluble solids. Also, the potassium present in vermicompost increases the accumulation of sugar in berries and the balance is N, P, K, which is essential for

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

the proper accumulation of sugar in fruits [34]. In strawberry [16, 19, 40], cucumber [9], tomato [1] and cabbage (*Brassica oleracea*) [26] the highest soluble solids were in vermicompost.

Vitamin C content

Vitamin C, which has a water-soluble structure, is a very important vitamin for protecting human health due to the presence of antioxidants in it. Vitamin C content depends on cultural practices, light intensity, weather conditions [34]. Different strawberry cultivars can have varying genetic traits that influence their nutrient composition, including vitamin C content. The Camarosa cultivar might naturally have a higher capacity for vitamin C synthesis and accumulation. Ascorbic acid is a biologically active form of vitamin C, the content of which can change with respect to growth and storage conditions and genetics of cultivars [46] Vitamin C content is also affected by plant nutrition, water availability and light intensity [48]. Vermicompost provides a wide range of nutrients for storage and microbial activity, and provides most nutrients available, such as N, P, Ca and exchangeable potassium for plant [40]. Having micronutrients such as iron, zinc, copper and manganese as well as high water and food storage capacity [42], can be considered as one of the reasons for the high level of vitamin C in the substrate based in vermicompost. The results of the present experiment with the results of other researchers on increase of vitamin C by vermicompost in tomatoes [1, 4], potatoes [38], cabbage [26], is consistent.

Conclusion

Based on the results obtained, the following conclusions can be drawn: The choice of substrate composition significantly influenced the growth and development of the strawberry plants.

Yield potential

The highest yield was observed in the Camarosa cultivar when grown in peat moss substrate. For Selva cultivar, the combination of 70% perlite and 30% vermicompost resulted in higher yields. These findings suggest that substrate composition plays a crucial role in determining the yield potential of different cultivars.

Cultivar-Specific responses

The two cultivars, Selva and Camarosa, exhibited variations in their responses to different substrate compositions. For instance, the Camarosa cultivar showed higher leaf number and chlorophyll index in peat moss-based substrates, while the Selva cultivar demonstrated higher fresh and dry root weights in the combination of perlite and vermicompost.

Quality attributes

The substrate composition also affected various quality attributes of the strawberries. The highest vitamin C content was observed in the Camarosa cultivar when grown in vermicompost, while the Selva cultivar exhibited higher total soluble solids (TSS) levels in the combination of perlite and vermicompost. These results highlight the potential of vermicompost-based substrates in enhancing fruit quality attributes. In conclusion, the choice of substrate composition in hydroponic strawberry cultivation has a significant impact on plant growth, yield, and quality attributes. Vermicompost can serve as a viable alternative to peat moss, with different cultivars exhibiting varying responses to substrate compositions.

Methods

The present study was done during 2019–2020 in Isfahan Agricultural and Natural Resources Research Center greenhouse (Isfahan Province, Iran) by hydroponic culture. Strawberry seedlings (Camarosa and Selva) were received from the agricultural center Kurdistan. For preparation of volumetric mixtures in order to eliminate the possible salinity of vermicompost culture substrate, leaching was performed on this substrate. No operation was performed on perlite and peat moss culture substrate. The experiment was performed in split plots as a randomized complete block design with 3 replications. The main treatment of culture substrate at four levels included volumetric mixture of 50% perlite and 50% peat moss (S_1), 70% perlite and 30% peat moss (S_2), 50% perlite and 50% vermicompost (S_3), and 70% perlite and 30% vermicompost (S_4) and sub-treatment were Camarosa and Selva.

The analysis of vermicompost and peat moss substrates are given in Table 3 and 4.

Table 3 properties of vermicompost used in the experiment

Vermicompost	K_2O %	P_2O_5%	N %	OM %	PH	EC (ds/m)
	1.30	1.70	1.05	49.0	7.3	1.2

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

The field capacity of used substrates was like this: FC: 50% perlite / 50% peat moss (S1):203%, FC: 70% perlite /30% peat moss (S2):145%, FC: 50% perlite/ 50% vermicompost (S3):59.5%, FC: 70% perlite / 30% vermicompost (S4):42.5%

For hydroponic planting, pots with an opening diameter of 18 cm were used and the nourishment method was open. Nutrient solution (including macro and micro nutrients from Table 5) needed by the plants was prepared in barrels (100 L) and 200 cc per pot was provided to the plants daily. The roots were immersed in Captan + Mancozeb fungicide solution for 2 s and immediately, 3 seedlings were planted in each pot. The greenhouse temperature was adjusted at 18 °C (night) and 25 °C (day) and relative humidity (60%) was considered constant for the treatments.

During the growing season, some of the most important morphological and biochemical indicators properties of cultivated pots (Fig. 8 Selva (Pic A) and Camarosa (Pic B) were estimated. Data acquisition started when the plants gave new leaves and continued until the end of the experiment. Traits were measured every 7 to 10 days and at the end an average was reported for each trait.

Total weight of fruits (yield)

When the fruits of the plants were fully ripe and had a uniform red color, the fruits were harvested and weighed with a digital scale model Electronic Compact Scale SF_400C.

Fresh/ dry weight of shoots and roots:

The roots and aerial parts were dried separately for 72 h in an oven at a temperature of 85 °C and then weighed with a scale with an accuracy of 0.01 [43].

Number of leaves and of inflorescences

Number of leaves and of inflorescences were counted.

Chlorophyll index

3 to 4 leaves were randomly selected from each plant and then measured using a chlorophyll meter model SPAD-502, Minolta, Osaka, Japan. The average value of leaf

Table 4 Properties of Peat moss used in the experiment

Peat moss	EC	pH Value H_2O	Amount of added fertilizer NPK fertilizer 14:10:18	Recommended use
	45 ms/m (±25%)	5.5- 6.5	1.5 kg/m^3	70 L

Peat moss: Produced by Klasmann -Deilmann GmbH40744Geeste.Germany

Table 5 Nutrients of soilless culture of strawberry in a general substrate [24]

Growth stage	Mg/l												Salinity ds/m
	N	P	K	Mg	Ca	S	Fe	Mn	Zn	B	Cu	Mo	
Vegetative Growth	207	65	184	58	221	77	6.5	2.6	0.25	0.7	0.07	0.05	2
Fruit Growing	182	82	301	58	148	77	6.5	2.6	0.25	0.7	0.07	0.05	2

Pic (A) Pic(B)

Fig. 8 pots of strawberry cultivation Selva (Pic **A**) and Camarosa (Pic **B**) in 4 volumetric mixtures. Abbreviations used: S_1:50% perlite / 50% peat moss, S_2: 70% perlite / 30% peat moss, S_3.50% perlite / 50% vermicompost and S_4.70% perlite /30% vermicompost. C_1: Selva and C_2: Camerosa

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

chlorophyll index was read in three replicates for each treatment.

Total soluble solids

Total soluble solids was displayed by refractometer device model PR-101Atago Co. Ltd., Japan, respectively.

Vitamin C content

Vitamin C content was determined by titration of potassium iodide [36].

Statistical analysis

The data were analyzed using MSTAT-C software and means were compared by Duncan's multiple range test at the probability level of 5%. Excel software was also used to draw the graphs.

Acknowledgements
We thank the Isfahan (Iran) Agricultural and Natural Resources Research Center.

Statement about the plants used
The strawberries (*Fragaria ananassa*) seedlings (Selva and Camarosa) that were used in this experiment are among the seedlings that are abundantly produced in suitable places for the growth of this fruit in this country (Iran). And they are part of the common and dominant cultivars in this region and are not rare and endangered species. cultivars of this experiment (Selva and Camarosa) were prepared from the Kurdistan city (Iran), which is one of the poles of strawberry. They are suitable cultivars for greenhouse production that producers use to produce and present strawberry products to the market. Experimental research and field studies on plants and collection of plant material was not against the institutional, national, and international guidelines and legislation.
This experiment is a university thesis related to the first author Mehsa Azizi Yeganeh who can get Ph.D. All scientific, practical and research stages of this experiment, from the preparation of seedlings to conducting experiments on plant samples with the cooperation of supervisors, consultants and co-authors, are in charge at the Center for Research, Education and Promotion of Agriculture and Natural Resources of Isfahan Province (Iran), It was carried out in accordance with the rules governing this organization and under the supervision of its officials and by obtaining the necessary permits to perform the various stages of this experiment from the various departments of this organization. It should be mentioned that the center for research, education and promotion of agriculture and natural resources of Isfahan province (Iran) is a government body with scientific, research, ethical and international approved rules and guidelines and has many official scientific members and researchers who publish international scientific articles approved by many annually. On the other hand, since this experiment is a university thesis, it has been tried to be under the scientific and ethical framework of the university.

Authors' contributions
MAY and A.a SH presented the main idea of the experiment. MAY, A.a SH and AE designed and performed the experiment. MAY and VA analyzed the data. A.a SH and AE performed the final examination of the experiment. All authors read and approved the final article.

Funding
This research did not receive any funding.

Availability of data and materials
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
We confirm that our study does not involve human subjects.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Horticultural Science and Agronomy, Science and Research Branch, Islamic Azad University, Tehran, Iran. [2]Soil and Water Research Department, Agricultural Research, Education and Extension Organization (AREEO), Isfahan Agricultural and Natural Resources Research and Education Center, Isfahan, Iran. [3]Department of Horticulture and Landscape Architecture, College of Agriculture and Natural Resources, The University of Tehran, Karaj, Iran.

Received: 8 April 2023 Accepted: 8 February 2024
Published online: 28 February 2024

References

1. Abduli MA, Amiri L, Madadian E, Gitipour S, Sedighian S. Efficiency of Vermicompost on Quantitative and Qualitative Growth of Tomato Plants. Int J Environ Res. 2013;7:467–72.
2. Abul-Soud MA, Emam MSA, Abd El-Rahman NG. The Potential Use of Vermicompost in Soilless Culture for Producing Strawberry. IJPSS. 2015;8:1–15.
3. Abdel-Razzak H, Alkoaik F, Rashwan M, Fulleros R, Ibrahim M. Tomato waste compost as an alternative substrate to peat moss for the production of vegetable seedlings. J Plant Nutr. 2018;42:1–9.
4. Ahirwar CHS, Hussain A. Effect of Vermicompost on Growth, Yield and Quality of Vegetable Crops. IJAPSA. 2015;1:49–56.
5. Ameri A, Tehranifar A, Shoor M, Davarynejad GhH. Effect of substrate and cultivar on growth characteristic of strawberry in soilless culture system. Afr J Biotechnol. 2012;11:11960–6.
6. Ansari AA, Kumar SK. Effect of Vermiwash and Vermicompost on soil parameters and productivity of okra (*Abelmoschus esculentus*) in Guyana. Afr J Agric Res. 2010;5:1794–8.
7. Arancon NQ, Edwards CA, Bierman P, Welch C, Metzer JD. Influence of Vermicomposts on field strawberries: effect on growth and yields. Bioresour Technol. 2004;93:145–53.
8. Atiyeh RM, Lee S, Edward CA, Arancon NQ, Metzger JD. The influence of humic acids derived from earthworm-processed organic wastes on plant growth. Bioresour Technol. 2002;84:7–14.
9. Azarmi R, Giglou MT, Taleshmikail RD. Influence of vermicompost on soil chemical and physical properties in tomato (*Lycopersicum esculentum*). Afr J Biotechnol. 2009;7:2397–401.
10. Cabilovski R, Manojlovic MS, Popovic´ BM, Radojc˘in MT, Magazin N, Petkovi´ CK, Kovacevic D, Lakicevi MD. Vermicompost and Vermicompost Leachate Application in Strawberry Production: Impact on Yield and Fruit Quality. Horticulturae. 2023;9:1–12.
11. Glaser B, Asomah AAA. Plant Growth and Chemical Properties of Commercial Biocharversus Peat-Based Growing Media. Horticulturae. 2022;8:2–13.
12. Joshi R, Singh J, Pal VA. Vermicompost as an effective organic fertilizer and biocontrol agent: effect on growth, yield and quality of plants. Rev Environ Sci Biotechnol. 2015;14:137–59.
13. Khan A, Ishaq F. Chemical nutrient analysis of different composts (vermicompost and pit compost) and their effect on growth of a vegetative crop Pisum sativum. Asian J Plant Sci Res. 2011;1:116–30.
14. Khatiwada A, Adhikari P. Effect of various organic fertilizers on seedling health and vigour of different varieties of cucumber in rautahat condition. MJSA. 2020;4:81–5.
15. Kilic N, Dasgan HY, Gruda NS. A Novel Approach for Organic Strawberry Cultivation: Vermicompost-Based Fertilization and Microbial Complementary Nutrition. Horticulturae. 2023;9:1–16.

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

16. Kumar N, Rama RB, Kumar Mishra P. Effect of vermicompost and Azotobacter on quality parameters of strawberry (*Fragaria* × *ananassa* Duch) CV Sweetcharlie. IJASR. 2015;5:269–76.
17. Kumar K, Shivani, Singh JP. Effect of vermicompost and phosphate solubilizing bacteria on growth and yield of potato (*Solanum tuberosum* L.). J Pharmacogn Phytochem. 2020;9:1454–6.
18. Ladan Moghadam AR, Ardebill ZO, Saidi F. Vermicompost induced changes in growth and development of Lilium Asiatic hybrid var. Navona Afr J Agric Res. 2012;7:2609–21.
19. Lakshmikanth H, Madaiah D, Sudharani N. Effect of Different Pot Culture Media on Biochemical and Quality Parameters of Strawberry in Vertical System. Int J Curr Microbiol App Sci. 2020;9:678–84.
20. Ma G, Mao H, Bu Q, Han L, Shabbir A, Gao F. Effect of Compound Biochar Substrate on the Root Growth of Cucumber Plug Seedlings. Agron. 2020;10:1–14.
21. Machado RMA, Alves-Pereira I, Morais C, Alemão A, Ferreira R. Effects of Coir-Based Growing Medium with Municipal SolidWaste Compost or Biochar on Plant Growth, Mineral Nutrition, and Accumulation of Phytochemicals in Spinach. Plants. 2022;11:2–15.
22. Mirakalaei SMM, Ardebill ZO, Mostafavi M. The effects of different organic fertilizers on the growth of lilies (*Lillium longiflorum*). IJBAS. 2013;4:181–6.
23. Mehraj H, Ahsan MK, Hussain MS, Rahman MM, Uddin AFMJ. Response of different organic matters of strawberry. Bangladesh Rese Public J. 2014;10:151–61.
24. Morgan L. Hydroponic Strawberry Production: a Technical Guide to the Hydroponic Production of Strawberries. Tokumaru, New Zealand: Suntec NZ Ltd; 2006. p. 118.
25. Moraditochaee M, Bozorgi HR, Halajisani N. Effects of vermicompost application and nitrogen fertilizer rates on fruit yield and several attributes of eggplant (Solanum melo ngena L.) in Iran. World Appl Sci J. 2011;15:174–8.
26. Nurhidayati N, Usman A, Murwani I. Yield and Quality of Cabbage (Brassica oleracea L.var. Capitata) Under Organic Growing Media Using Vermicompost and Earthworm Pontoscolex corethrurus Inoculation. Agric Agric Sci Proc. 2016;11:5–13.
27. Oberpaur Ch, Puebla V, Vaccarezza F, Arévalo ME. Preliminary substrate mixtures including peat moss (*Sphagnum magellanicum*) for vegetable crop nurseries. Cien Inv Agr. 2010;37:123–32.
28. Pant AP, Radovich TJK, Hue NV, Miyasaka SC. Pak Choi (*Brassica rapa*, Chinensis Group) Yield, Phytonutrient Content, and Soil Biological Properties as Affected by Vermicompost-to-water Ratio Used for Extraction. Hort Scienc. 2012;47:395–402.
29. Papathanasiou F, Papadopoulos I, Tsakiris I, Tamoutsidis E. Vermicompost as a soil supplement to improve growth, yield and quality of lettuce (Lactuca sativa L.). J Food Agric Environ. 2012;10:677–82.
30. Paul S, Bhattacharya SS. Vermicomposted water hyacinth enhances growth and yield of marigold by improving nutrient availability in soils of north bank plain of Assam. Res Rev J Agric Sci Technol. 2012;2:36–46.
31. Rahim Doust J, Nazarideljou MJ, Arshad M, Ferrante A. Comparison of the Growth, Physio-Biochemical Characteristics, and Quality Indices in Soilless-Grown Strawberries under Greenhouse and Open-Field Conditions. Horticulturae. 2022;9:2–15.
32. Regmi A, Singh S, Moustaid-Moussa N, Coldren C, Simpson C. The Negative Effects of High Rates of Biochar on Violas Can Be Counteracted with Fertilizer. Plants. 2022;11:1–15.
33. Rehman S, Castro F, Aprile A, Benedetti M, Fanizzi FP. Vermicompost: Enhancing Plant Growth and Combating Abiotic and Biotic Stress. Agronomy. 2023;13:1–25.
34. Sayg H. Effects of Organic Fertilizer Application on Strawberry (Fragaria vesca L.) Cultivation. Agronomy. 2022;12:1–15.
35. Shahbazi M, Chamani E, Shahbazi M, Mostafavi M, Pourbeirami EHir Y. Investigation of Media (Vermicompost, Peat and Coco - Peat) on Growth and Flowering of Carnation Flower. Agri Know Sust Prod. 2012;22:127–36 ((In Persian)).
36. Shafiee M, Taghavi TS, Babalar M. Addition of salicylic acid to nutrient solution combined with postharvest treatments (hot water, salicylic acid, and calcium dipping) improved postharvest fruit quality of strawberry. Sci Hortic. 2010;124:40–5.
37. Shahzad U, Ijaz M, Noor N, Shahjahan M, Hassan Z, Kahn AA, Calica P. Variations in Growing Media and Plant Spacing for the Improved Production of Strawberry(*Fragaria ananassa* cv. Chandler). Philippine J Sci. 2018;147:711–9.
38. Shambhavi SH, Sharma RP. Influence Of Vermicompost On Potato (*Solanum Tuberosum*) In Wet Temperate Zone Of Himachal Pradesh. Indian J Plant Physiol. 2008;13:185–90.
39. Sharma S, Rana VS, Rana N, Sharma U, Gudeta K, Alharbi K, Ameen F, Bhat SA. Effect of Organic Manures on Growth, Yield, Leaf Nutrient Uptake and Soil Properties of Kiwifruit (Actinidia deliciosa Chev) cv Allison. Plants. 2022;11:1–14.
40. Singh R, Sharma RR, Kumar S, Gupta RK, Patil RT. Vermicompost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (*Fragaria x ananassa* Duch.). Bioresour Technol. 2008;99:8507–11.
41. Singh AK, Nayyer A, Singh A, Rai D, SinghA P, Rai A. Effect of FYM and vermicompost on growth and yield on strawberry (Fragaria×ananassa Duch.) cv. Camarosa. Pharm Innov J. 2022;11:1803–6.
42. Tabatabai S. The production of vermicompost is a step towards the production of organic products (with a practical attitude). Persian: Tehran, Agricultural Education and Promotion Publications. 2013;102p.
43. Tavousi M. and Shahin Rakhsar P. The effect of four types of substrate material on the yield and some parameters of strawberry growth in soilless cultivation. Sci res Jour. Agri. sci. 2010;4:83–94
44. Thuy PT, Nghia NTA, Dung PT. Effects of Vermicompost Levels on the Growth and Yield of HT152 Tomato Variety Grown Organically. IJAIR. 2017;5:513–8.
45. Thoudam J, Kotiyal A. Effect of Biofertilizers and Organic Fertilizers on Growth and Yield of Strawberry cv Camarosa. The Pharma Innovation Journal. 2022;11:2324–7.
46. Van De Velde F, Tarola AM, Güemes D, Pirovani ME. Bioactive Compounds and Antioxidant Capacity of Camarosa and Selva Strawberries (*Fragaria* × *ananassa* Duch). Foods. 2013;2013(2):120–31.
47. Vaidyanathan G, Vijayalakshmi A. Effect of vermicompost on growth and yield of Tomato. Eur J Pharm Med Res. 2017;4:653–6.
48. Zaller JG. Vermicompost as a substitute for peat in potting media: Effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. Sci Hortic. 2007;112:191–9.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

Terms and Conditions

Springer Nature journal content, brought to you courtesy of Springer Nature Customer Service Center GmbH ("Springer Nature").

Springer Nature supports a reasonable amount of sharing of research papers by authors, subscribers and authorised users ("Users"), for small-scale personal, non-commercial use provided that all copyright, trade and service marks and other proprietary notices are maintained. By accessing, sharing, receiving or otherwise using the Springer Nature journal content you agree to these terms of use ("Terms"). For these purposes, Springer Nature considers academic use (by researchers and students) to be non-commercial.

These Terms are supplementary and will apply in addition to any applicable website terms and conditions, a relevant site licence or a personal subscription. These Terms will prevail over any conflict or ambiguity with regards to the relevant terms, a site licence or a personal subscription (to the extent of the conflict or ambiguity only). For Creative Commons-licensed articles, the terms of the Creative Commons license used will apply.

We collect and use personal data to provide access to the Springer Nature journal content. We may also use these personal data internally within ResearchGate and Springer Nature and as agreed share it, in an anonymised way, for purposes of tracking, analysis and reporting. We will not otherwise disclose your personal data outside the ResearchGate or the Springer Nature group of companies unless we have your permission as detailed in the Privacy Policy.

While Users may use the Springer Nature journal content for small scale, personal non-commercial use, it is important to note that Users may not:

1. use such content for the purpose of providing other users with access on a regular or large scale basis or as a means to circumvent access control;
2. use such content where to do so would be considered a criminal or statutory offence in any jurisdiction, or gives rise to civil liability, or is otherwise unlawful;
3. falsely or misleadingly imply or suggest endorsement, approval , sponsorship, or association unless explicitly agreed to by Springer Nature in writing;
4. use bots or other automated methods to access the content or redirect messages
5. override any security feature or exclusionary protocol; or
6. share the content in order to create substitute for Springer Nature products or services or a systematic database of Springer Nature journal content.

In line with the restriction against commercial use, Springer Nature does not permit the creation of a product or service that creates revenue, royalties, rent or income from our content or its inclusion as part of a paid for service or for other commercial gain. Springer Nature journal content cannot be used for inter-library loans and librarians may not upload Springer Nature journal content on a large scale into their, or any other, institutional repository.

These terms of use are reviewed regularly and may be amended at any time. Springer Nature is not obligated to publish any information or content on this website and may remove it or features or functionality at our sole discretion, at any time with or without notice. Springer Nature may revoke this licence to you at any time and remove access to any copies of the Springer Nature journal content which have been saved.

To the fullest extent permitted by law, Springer Nature makes no warranties, representations or guarantees to Users, either express or implied with respect to the Springer nature journal content and all parties disclaim and waive any implied warranties or warranties imposed by law, including merchantability or fitness for any particular purpose.

Please note that these rights do not automatically extend to content, data or other material published by Springer Nature that may be licensed from third parties.

If you would like to use or distribute our Springer Nature journal content to a wider audience or on a regular basis or in any other manner not expressly permitted by these Terms, please contact Springer Nature at

onlineservice@springernature.com