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Research Article

Effects of vermicompost as an alternative substrate on yield and quality of cauliflower and pepper seedlings

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Abstract

It is wondered whether vermicompost can be an alternative to peat in seedling production. Therefore, this study investigated the effects of different vermicompost rates on the growth, quality characteristics and macro and micro mineral concentrations of pepper and cauliflower seedlings. There were 4 treatments consisting of different mixtures in the study. T1: 70% peat + 27% perlite + 3% vermiculite; T2: 70% vermicompost + 27% perlite + 3% vermiculite; T3: 35% peat + 35% vermicompost + 27% perlite + 3% vermiculite; T4: 100% vermicompost. 'Sivrillo' F_1 (*Capsicum annuum* var. *longum*) pepper and 'Casper' F_1 (*Brassica oleraceae* var. *botrytis)* cauliflower varieties were used as the plant material. Vermicompost mixtures had a significant impact on pepper and cauliflower seedlings. The emergence and growth characteristics of pepper seedlings were similar in T1, T2 and T3 treatments. However, the T3 mixture provided the highest emergence rate and seedling height in cauliflower seedlings. T3 also increased the leaf area both pepper and cauliflower seedlings more than the other treatments. Although T2 medium showed the highest N, K, and Mg contents in pepper seedlings, vermicompost mixtures had the highest P, K, Ca, and Mg concentrations in cauliflower. Vermicompost mixtures had higher microelement contents in cauliflower, whereas similar results were obtained from T2 and T1 treatments in pepper seedlings. In conclusion, it was determined that the 35% peat and 35% vermicompost mixture was appropriate for pepper and cauliflower seedlings in terms of many criteria. Additionally, noteworthy results were obtained when 70% peat was substituted with vermicompost.

Keywords: cauliflower; mineral concentration; peat; pepper; vermicompost; quality

Introduction

The choice of a suitable substrate is crucial for the success of seedling cultivation (Jankauskienė *et al.*, 2022). The substrates used should be rich in plant nutrients, have adequate water retention and aeration. Besides, they should be cost-effective (Basheer and Agrawal, 2013).

Peat is one of the most studied and used substrates in the world due to its high nutrient exchange and physical properties (Raviv *et al.*, 1986). In addition, it is protected by the European Community Decisions of 1992 and is considered a non-renewable resource (Olaria *et al.*, 2016). Ecological and environmental concerns against the use of peat are increasing due to the destruction of wetland ecosystems (Robertson, 1993). Furthermore, rapidly rising peat prices, increased carbon emissions during peat extraction, and the depletion

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of peat resources are raising concerns (Jayasinghe *et al*., 2010; Haitao, 2018a). Considering that peat contributes to 23% of the overall expense of seedling production (Pascual *et al*., 2018), the current emphasis is on exploring new cost-effective alternatives to peat. Recently, the use of vermicompost in vegetable cultivation has received increasing interest and attention (Basheer and Agrawal, 2013; Haitao, 2018b). Compared to non-renewable peat sources, vermicompost has many resources, making it an environmentally friendly material (Makowski *et al*., 2019).

Vermicomposting is the composting of organic waste by earthworms. This organic material, formed by the interaction between earthworms and microorganisms, contains plant nutrients and some plant growth regulators (Edwards *et al*., 2010; Kaya and Coşkun, 2020). 90% of vermicompost aggregates are water resistant (Dominguez *et al*., 1997; Winsome and McColl, 1998; Atiyeh *et al*., 2000a). Vermicompost is also an important ecological alternative to mineral fertilisers. In addition, it contains enzymes, soil antibiotics, humic substances, growth and development hormones, macro and micronutrients (Atiyeh *et al*., 2001; Prabha *et al*., 2007). As vermicompost is similar to peat in terms of high porosity, aeration, drainage and water holding capacity (Dominguez and Edwards, 2011), it can be used alone or mixed with peat to produce vegetable seedlings (Kaciu *et al*., 2011). Vermicompost is mainly used in outdoor horticulture and there is limited information on its use in seedling production. Vermicompost is mainly used in outdoor horticulture and there is limited information on its use in seedling production. However, studies indicated its potential benefits when added to substrate at a ratio of 10-20% (Bachman and Metzger, 2008).

Some studies demonstrated that vermicompost stimulates seed germination, promotes vegetative growth and root development, and can improve seedling quality (Atiyeh *et al.*, 2000b; Paul and Metzger, 2005). The growth of eggplant and pepper seedlings was stimulated when 20-40% vermicompost was added to commercial growing media (Arancon *et al*., 2004; Paul and Metzger, 2005), and the growth of lettuce seedlings was stimulated when 20-50% was added (Ali *et al*., 2007). In a study conducted on watermelon under field conditions, the highest germination rate (93.3%) was found in the 300 kg da^{-1} application of vermicompost and the highest yield per plant was found in the 600 kg da^{-1} application of vermicompost. There was no significant difference between treatments in terms of fruit number, SCC, pH, fruit width, peel thickness, leaf chlorophyll content, total sugar content, total phenolic compound and vitamin C contents (Ak Göksu and Öztokat Kuzucu, 2017). Mixing vermicompost with peat at various rates had a beneficial impact on tomato seedlings performance, improved their fruits quality, and was therefore recommended as an environmentally friendly alternative to peat (Zaller, 2007). Pour *et al*. (2013) revealed that the effect of vermicompost on cabbage seedlings was not only related to nutrients, but also affected hormonal and biochemical properties, and if used in excessive amounts, it could have negative effects and be uneconomical. In addition to these positive results, Ievinsh (2011) realised that vermicompost may have negative effects on seed germination and seedling growth and reported that the optimal amount of vermicompost in the substrate is important. Ceritoglu *et al*., (2021) reported that vermicompost mixed at 10% and 20% had a supportive effect at the germination and seedling stages of grain legumes, and as the dose increased, vermicompost had an inhibitory effect due to its pH.

This study was conducted to determine the effects of different rates of vermicompost and peat mixture on growth and development characteristics, wet weight, dry weight, chlorophyll and plant nutrient contents of cabbage and pepper seedlings. The main hypothesis of the research was to identify a substance that could substitute the widely utilised peat and the appropriate ratio.

Materials and Methods

Research area and climatic characteristics

The research was conducted in April and May 2019 at the seedling production facilities of Kircami Seedling Ltd. Co. in Antalya, Turkey (30° 52′ 40″ E and 36° 54′ 34″ N). The research area was covered with a high type plastic greenhouse with a spring roof. The seedlings were grown under fully controlled conditions. The seedlings were irrigated with a boom irrigation system. Temperature and humidity in the seedling production greenhouse were recorded with a digital temperature-humidity meter. The climatic characteristics of the greenhouse are shown in Figure 1.

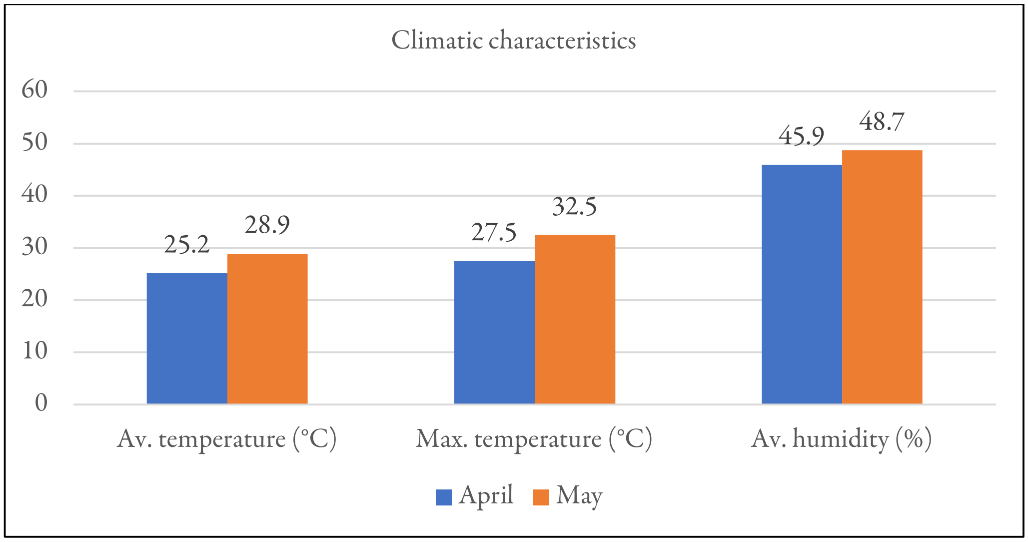

Figure 1. Average temperature, humidity and maximum temperature values recorded in the seedling production greenhouse during the research period

Experimental design

This research was carried out according to the randomized plots experimental design with a total of 4 treatments and 3 replications. There were 216 seedlings in each replicate. In the ready seedling sector in Turkey, 70% peat, 27% perlite and 3% vermiculite as covering material are generally used in seedling production. This mixture was considered as a control in this experiment. Some seedling companies may change the proportions of these materials within the scope of their commercial activities. After sowing the vegetable seeds with a pneumatic machine, the seedling trays were transferred to the germination room at 25 °C and 80% humidity. When the seedlings started to emerge on the medium, they were removed from the germination chamber and the trays were placed on stands in the greenhouse. The treatments and their abbreviations are given in Table 1.

Table 1. Treatments and abbreviations in the research

Abbreviations	Treatments
T1-(C)	70% Peat + 27% Perlite + 3% Vermiculite-Control
T2	70% Vermicompost + 27% Perlite + 3% Vermiculite
T3	35% Peat + 35% Vermicompost + 27% Perlite + 3% Vermiculite
T4	100% Vermicompost

Seedling media and their characteristics

The physical and chemical properties of the seedling media used in the experiment were analysed according to Kaçar (1995) and Kaçar and Kovancı (1982). Table 2 presents the properties of the seedling media based on the analysis.

Table 2. Characteristics of the growing media used in the study

Characteristics of media	T1	T2	T3	T4
pH	5.7	8.4	7.7	8.4
EC (mS/cm)	493	1498	1191	1959
Lime (%)	1.6	18.3	6.6	19.9
Relative Humidity (%)	57.263	26.163	37.052	9.23
Water holding capacity (%)	542.59	187.88	277.71	159.91
Organic matter (%)	60.86	30.28	37.39	33.55
Ash (%)	39.14	69.72	62.61	66.45
Total Nitrogen (N) (%)	1.6	4.5	3.6	6.6
Available phosphorus (P) (ppm)	89.1	39	74.4	52
Available potassium (K) (ppm)	264.9	2545.5	193.2	3615
Available calcium (Ca) (ppm)	241.4	150.7	193.3	204.9
Available magnesium (Mg) (ppm)	105.2	145.7	167.3	179.7
Available iron (Fe) (ppm)	0.19	0.8	2.27	1.39
Available manganese (Mn) (ppm)	0.51	trace	0.35	trace
Available zinc (Zn) (ppm)	0.04	0.005	0.09	0.06
Available copper (Cu) (ppm)	trace	0.23	0.08	0.65

Plant material

Sivrillo F_1 (*Capsicum annuum* var. *longum* cv. 'Sivrillo F_1') hot pepper and Casper F_1 (*Brassica oleraceae* var. *botrytis* cv. 'Casper F_1') cauliflower varieties were used as plant material in the study.

Criteria examined in the research

The emergence rate (%), emergence time (days), emergence index, seedling height (cm), seedling thickness (mm), hypocotyl height (cm), epicotyl height (cm), number of true leaves (per plant), total chlorophyll content (SPAD), fresh weight (g), dry weight (%), and macro (N, P, K, Ca, Mg) and micro (Fe, Zn, Mn, Cu) mineral contents of pepper and cauliflower seedlings were analysed.

The emergence rate was calculated using the formula "number of seedlings emerging on the growing medium / total number of seeds sown x 100". The average emergence time was determined using the following formula (Ellis and Roberts, 1981):

$$ET = \Sigma(Dn) / \Sigma n$$

ET: Mean emergence time; n: Number of emerged seeds on day D; D: number of days counted from the beginning of emergence

The emergence index was calculated according to the following formula below using (Copeland and McDonald, 2001).

$$EI = \Sigma n / \Sigma d$$

EI: Emergence index, n: Number of seedlings emerged in d days, d: Number of days since the start of the emergence test

The total chlorophyll content in the leaves of pepper and cauliflower seedlings was measured using a SPAD 502 chlorophyll meter (SPAD; Minolta, Tokyo, Japan). The macro and micro mineral concentrations of seedlings were analysed according to Kacar (1995) and Kacar and Kovancı (1982). Chlorophyll measurement on pepper seedlings and cauliflower seedlings is shown in Figure 2.

(a) (b)

Figure 2. (a) SPAD measurement on pepper seedlings, (b) cauliflower seedlings

Statistical analysis

The data obtained from the study were subjected to analysis of variance (ANOVA) using SAS (Version 9.00; SAS Institute Inc., Cary, NC, USA) Statistical Package Program, and the LSD test was used to compare means with a significance level of $p<0.05$.

Results and Discussion

Seedling emergence characteristics

The different vermicompost treatments had a significant effect ($p<0.05$) on the emergence of long pepper and cauliflower seedlings (Table 3). The lowest emergence rate and the longest emergence time on the medium after germination were recorded in the T4 treatment. Emergence rates in both the T2 and T3 mixtures were similar to the T1 (C), which is widely used in seedling production. In this case, the best emergence index values were observed in the T1, T2 and T3 treatments. When the same media were compared in cauliflower seedlings, the highest emergence rate was found in the T3 mixture. The T1 treatment resulted in the earliest emergence in cauliflower seedlings. When the emergence times of both pepper and cauliflower seedlings were compared, there was a difference of 1-2 days compared to the longest emergence time. On analyzing the emergence index values, a performance similar to that of pepper seedlings was obtained.

Table 3. Effects of vermicompost treatments on emergence of pepper and cauliflower seedlings

Pepper	**T1-(C)**	**T2**	**T3**	**T4**
Emergence rate (%)	85.49 ± 2.16* a	81.63 ± 0.15 a	83.03 ± 1.63 a	64.81 ± 3.25 b
Emergence time (day)	8.00 ± 0 b	8.00 ± 0 b	8.00 ± 0 b	9.00 ± 0 a
Emergence index	17.13 ± 0.35 a	16.36 ± 0.05 a	16.45 ± 0.24 a	10.41 ± 0.69 b
Cauliflower				
Emergence rate (%)	93.36 ± 0.89 b	93.06 ± 0.67 b	96.91 ± 0.86 a	93.68 ± 0.62 b
Emergence time (day)	3.00 ± 0.00 c	3.67 ± 0.33 b	5.00 ± 0.00 a	5.00 ± 0.00 a
Emergence index	46.45 ± 0.50 ab	46.35 ± 0.67 ab	47.58 ± 0.40 a	45.73 ± 0.27 b

Data are shown as the mean.

* ± standard error, different letters indicate a difference between treatments ($p < 0.05$).

Based on the emergence performance of pepper and cauliflower seedlings, the vermicompost mixtures were found to be effective. It is crucial that these mixtures provide similar or superior results compared to the medium (C) used in commercial seedling production. Some research results support our results. Fernandez-Luqueno *et al*. (2010) reported that the presence of minerals like P and K stimulated kidney bean emergence with the use of vermicompost. In a recent study, Ma *et al*. (2022) discovered that adding vermicompost to the growing medium resulted in a 30.4% increase in germination and a 57.8% increase in the seedling index. Truong and Wang (2015) found greater emergence and elongation of seedlings for both tomato cultivars in a mixture consisting of equal parts vermicompost, rice husk ash, and coconut fibre. In a study exploring alternatives to peat for watermelon seedlings, vermicompost and peat produced similar emergence rates (Rivera *et al*., 2022). Mixing pine bark and chicken manure vermicompost between 25% and 50% resulted in more than 90% emergence rate in tomato and cabbage seedlings due to optimal physical properties (Mupambwa *et al*., 2017a). Muhie (2020) increased the emergence rate of onion seedlings that were primed with vermicompost.

In our research, the lowest values and negative results for seedling emergence were obtained from the vermicompost experiment used alone (T4). It can be said that this result is caused by the high EC and pH values of vermicompost (Table 2). Similar results were also reported by Truong and Wang (2015). Ceritoglu *et al*. (2021) also reported that pH can have an inhibitory effect.

Seedling growth characteristics

The growth characteristics of pepper and cauliflower seedlings (excluding seedling thickness, root collar diameter and number of leaves in cauliflower) were influenced by the vermicompost treatments (Table 4). The lowest values for seedling height, hypocotyl height and epicotyl height were recorded in T4 treatment. Similar results to T1 were obtained from T2 and T3 treatments in pepper seedlings. Seedling thickness is a crucial quality criteria. Similar results were obtained from T1 and T3 treatments regarding seedling thickness and root collar diameter. Additionally, T1 and T2 treatments displayed similar characteristics in terms of leaf number. These results show that these two prominent media can be an alternative for pepper.

The seedling height of cauliflower was longer in T1 and T3 treatments than in the other treatments, whereas the shortest seedling height was recorded in treatment T4. Moreover, hypocotyl and epicotyl heights were higher in the T1 treatment. Vermicompost treatments had no impact on the seedling thickness, root collar diameter and leaf number of cauliflower.

Table 4. Effects of vermicompost treatments on seedling growth characteristics

Pepper	T1-(C)	T2	T3	T4
Seedling height (cm)	13.84 ± 0.39* a	13.71 ± 0.57 a	14.51 ± 0.35 a	12.35 ± 0.26 b
Hypocotyl height (cm)	3.41 ± 0.15 a	3.17 ± 0.12 ab	3.14 ± 0.03 ab	3.01 ± 0.02 b
Epicotyl height (cm)	7.09 ± 0.25 a	7.66 ± 0.12 a	7.61 ± 0.20 a	6.41 ± 0.24 b
Seedling thickness (mm)	2.45 ± 0.01 ab	2.13 ± 0.16 c	2.54 ± 0.08 a	2.16 ± 0.06 bc
Root collar diameter (mm)	2.63 ± 0.09 a	2.12 ± 0.19 c	2.52 ± 0.09 ab	2.20 ± 0.05 bc
Number of leaves (per plant)	7.44 ± 0.15 a	7.22 ± 0.06 ab	7.10 ± 0.05 b	7.07 ± 0.00 b
Cauliflower				
Seedling height (cm)	9.76 ± 0.16 a	7.74 ± 0.12 b	9.03 ± 0.41 a	6.48 ± 0.14 c
Hypocotyl height (cm)	2.22 ± 0.06 a	1.57 ± 0.07 bc	1.79 ± 0.03 b	1.51 ± 0.10 c
Epicotyl height (cm)	2.51 ± 0.21 a	1.66 ± 0.104 bc	1.92 ± 0.13 b	1.30 ± 0.19 c
Seedling thickness (mm)	4.56 NS	4.47 NS	4.44 NS	4.37 NS
Root collar diameter (mm)	2.58 NS	2.43 NS	2.52 NS	2.44 NS
Number of leaves (per plant)	6.60 NS	6.16 NS	6.27 NS	6.11 NS

Data are shown as the mean.

* ± standard error, different letters indicate a difference between treatments ($p < 0.05$).

NS: Not Significant

The improvement of growth characteristics by vermicompost may be due to the nitrogen content of the media (Table 2), as reported by Cavalcante *et al*. (2019). According to Gruffman *et al*. (2012), N is an essential element for promoting seedling growth. Several studies have established that the addition of vermicompost to the growing medium increased the growth of tomato, pepper and cucumber seedlings (Atiyeh *et al*. 2000;

Arancon *et al*., 2004; Azarmi *et al*., 2008; Jankauskiene *et al*., 2022). Sallaku *et al*. (2009) found that vermicompost application increased cucumber growth compared to commercial peat. According to Ma *et al*. (2022), the optimal rate of vermicompost to improve plant growth characteristics was 40-60%. In a different study focusing on 2 tomato varieties, Truong and Wang (2015) observed that mixing rice husk ash and coconut fibre with various ratios of vermicompost produced mixtures that enhanced seedling diameter, height, and the number of leaves. The minimum values were determined in the single use of vermicompost treatment, which is consistent with our results.

Olaria *et al*. (2016) supplemented vermicompost to coconut husk, compared it with peat and recorded the maximum height for tomato seedlings in a 30% vermicompost mixture. Conversely, they found the highest value for eggplant seedlings in 100% peat substrate. The growth of tomato and pepper seedlings improved significantly in a mixture containing 60% vermicompost and 30% peat. Rivera *et al*. (2022) demonstrated that seedling height, diameter and number of true leaves in both watermelon varieties were similar to peat in a study comparing media containing vermicompost. Moreover, in a study evaluating pine bark and chicken manure vermicompost, the maximum seedling heights of tomato and cabbage were achieved with 25-50% mixtures (Mupambwa *et al*., 2017a). When vermicompost extracts (10%, 5%, 3%, 1%) derived from chicken manure were applied to a peat-perlite medium, the height of tomato and lettuce seedlings increased gradually with an increase in extract ratio. The maximum seedling height was achieved at the 5% vermicompost extract concentration, when different extract ratios 20%, 10%, 5%, 1%, and 0% were applied (Arancon *et al*., 2012). Meanwhile, Haitao *et al*. (2018a) demonstrated that a mixture of vermicompost and vermiculite promoted strong pepper seedling growth. The lowest results obtained from T4 in our study indicate a possible correlation with the tightness of the medium and quality of root aeration, as described by Pascual *et al*. (2018). Our results support studies recommending that although vermicompost is rich in essential nutrients, it should be mixed up to 50% in mixtures (Lazcano *et al*., 2009; Mupambwa *et al*., 2017b).

Leaf area, wet weight, dry weight and chlorophyll content of seedlings

The treatments of vermicompost had a significant impact on the leaf area, wet weight, dry weight and chlorophyll content of pepper and cauliflower seedlings (Table 5). The highest leaf area in pepper seedlings was obtained from T3 treatment. T3 treatment produced 22.54% more leaf area than T4, 40.20% more leaf area than T2 and 18.75% more leaf area than T1. Meanwhile, the highest wet weight was measured in the T1, whereas the minimum value was observed in the T4. Both T1 and T2 treatments had higher dry weights compared to the other treatments. Additionally, the T1 treatment resulted in the highest content of chlorophyll in pepper.

Table 5. Effects of vermicompost treatments on leaf area, wet weight, dry weight and chlorophyll content of pepper and cauliflower seedlings

Pepper	T1-(C)	T2	T3	T4
Leaf area (cm^2)	13.92 ± 0.73* b	11.79 ± 1.03 b	16.53 ± 0.57 a	13.49 ± 0.52 b
Wet weight (g)	392.33 ± 7.53 a	281.67 ± 6.69 c	357.00 ± 9.02 b	182.67 ± 10.33 d
Dry weight (g)	10.78 ± 0.38 a	10.12 ± 0.21 ab	9.91 ± 0.04 b	9.53 ± 0.12 b
Chlorophyll contents (SPAD)	47.33 ± 0.81 a	44.63 ± 0.27 b	44.97 ± 0.33 b	38.03 ± 0.45 c
Cauliflower				
Leaf area (cm^2)	25.82 ± 0.59 ab	25.46 ± 0.94 b	28.49 ± 1.10 a	20.56 ± 0.77 c
Wet weight (g)	1125.00 ± 35.47 a	970.00 ± 35.12 b	1156.67 ± 23.33 a	841.33 ± 25.58 c
Dry weight (g)	7.44 ± 0.07 a	6.48 ± 0.04 b	6.35 ± 0.22 b	7.27 ± 0.10 a
Chlorophyll contents (SPAD)	50.93 ± 0.12 a	47.50 ± 0.89 b	47.43 ± 0.35 b	49.90 ± 0.72 a

Data are shown as the mean.

* ± standard error, different letters indicate a difference between treatments ($p < 0.05$).

The higher leaf area of cauliflower seedlings was found in T3 and T1 treatments, respectively. Seedlings grown in the T3 mixture had 10.34% more leaf area than T1, 11.90% more leaf area than T2 and 38.57% more leaf area than T4. Furthermore, both T3 and T1 had the highest wet weight, whereas T1 and T4 had the highest dry weight. Although the seedlings in these treatments had lower values for characteristics such as height and thickness, their dry weight was higher. The highest values for total chlorophyll were recorded in T1 and T4 treatments. There are many studies reporting different results for these criteria. Rivera *et al*. (2022) reported that vermicompost and peat media provided similar results with respect to leaf area and biomass ratios in two different watermelon cultivars. Ma *et al*. (2022) found that vermicompost in the growing medium increased total biomass by 54.4%. Mupambwa *et al*. (2017a) discovered that the leaf area of tomato and cabbage seedlings was highest in mixtures of 25-50% chicken manure vermicompost and pine bark. Haitao *et al*. (2018a) indicated that a compost+vermiculite mixture gave better results in pepper seedlings than a peat + vermiculite mixture. Zaller (2007) revealed the greatest dry weight in tomatoes that were cultivated after applying 60% vermicompost in tomato seedlings. Kumar and Raheman (2012) determined that a potting mix of 25% vermicompost and 75% soil and sand mixture in pots filled equally by volume was the best for tomato, eggplant and pepper. Haitao *et al*. (2018b) reported that the chlorophyll content of tomato seedlings was predominantly influenced by the nature of vermicompost and the seedling growth period. Olaria *et al*. (2016) conducted an experiment using mixtures of peat, coconut shell, and vermicompost. The results showed that the coconut shell mixture produced the lowest fresh and dry weights of tomato, pepper, and eggplant seedlings.

In a separate study on tomato seedlings, SPAD measurements were highest in the 100% peat medium, while for pepper and eggplant, they were higher in a 30% vermicompost mixture. The leaf chlorophyll content was reduced when vermicompost was used alone (Ali *et al*., 2007). However, Uma and Malathi (2009) observed a positive impact of vermicompost on chlorophyll in Amaranthus plants after germination. The changes in leaf chlorophyll content in our study may be due to the mechanism of photosynthesis and the effect of vermicompost on some components related to photosynthesis as reported by Alonso *et al*. (2002) and Ievinsh (2011).

In this study, the values leaf area, wet weight and dry weight (except cauliflower) of pepper and cauliflower seedlings were lower in T4. As seen in Table 2, the lower values obtained despite the N content of T4 are directly related to the medium. Pascual *et al*. (2018) supported these results by pointing out the aeration of the roots, that is, the tightness of the medium. In contrast, Cavalcante *et al*. (2019) emphasized the significance of nitrogen for plant growth, specifically leading to more foliage and root biomass. This points to the use of vermicompost in mixtures.

Macroelement concentrations of seedlings

Table 6 shows that pepper and cauliflower seedlings utilised varying quantities of macro minerals in the growing media. The highest N in pepper seedlings was determined in T1 and T2 media. Meanwhile, the highest P content was found in seedlings grown in T1 medium. The highest K and Mg contents were analysed in T2. The highest N concentration in cauliflower seedlings was obtained from T1 and T4 media. The lowest P was determined in the T1 treatment, while it was higher in the other treatments. It can be said that vermicompost media feed cauliflower seedlings better in terms of P. Regarding K, the highest value was found in T3, while both T2 and T3 treatments had higher Ca concentrations. Additionally, T3 medium provided the best nourishment for cauliflower seedlings.

Table 6. Effects of vermicompost treatments on macroelement concentrations in seedlings of pepper and cauliflower

Pepper	T1-(C)	T2	T3	T4
N	10.78 ± 0.38* a	10.12 ± 0.21 ab	9.91 ± 0.04 b	9.53 ± 0.12 b
P	7.33 ± 0.18 a	6.45 ± 0.05 bc	6.30 ± 0.10 c	6.68 ± 0.02 b
K	0.56 ± 0.01 b	0.61 ± 0.02 a	0.57 ± 0.01b	0.57 ± 0.01 b
Ca	5.55 NS	5.89 NS	5.91 NS	5.60 NS
Mg	0.62 ± 0.03 b	0.77 ± 0.05 a	0.71 ± 0.01 ab	0.75 ± 0.03 a
Cauliflower				
N	7.44 ± 0.07 a	6.48 ± 0.04 b	6.35 ± 0.22 b	7.27 ± 0.10 a
P	5.58 ± 0.14 b	5.78 ± 0.16 ab	5.77 ± 0.16 ab	6.04 ± 0.00 a
K	0.75 ± 0.01 b	0.71 ± 0.01 c	0.81 ± 0.01 a	0.66 ± 0.01 d
Ca	5.96 ± 0.19 b	7.08 ± 0.19 a	6.89 ± 0.02 a	6.07 ± 0.26 b
Mg	1.07 ± 0.01 b	1.10 ± 0.03 b	1.24 ± 0.05 a	0.96 ± 0.02 c

Data are shown as the mean.
* ± standard error, different letters indicate a difference between treatments ($p < 0.05$).
NS: Not Significant

Truong and Wang (2015) reported that changes in the dosage of vermicompost significantly affected the macro element contents in seedlings, except for P, in their study of two different varieties of tomatoes. Zaller (2007) discovered varying levels of macro element contents in fruits obtained from different tomato seedling varieties grown using peat-vermicompost mixtures at various ratios. However, the results were notably effective. Meanwhile, Jankauskiene *et al.* (2022) stated that phosphorus and calcium contents of cucumber seedlings were not affected in peat-vermicompost mixtures, while nitrogen, potassium and magnesium contents were analysed as the highest in 30% mixture. Tavalı *et al.* (2013) demonstrated that vermicompost positively affected K concentration in cauliflower due to the amount of potassium in the vermicompost. In another experiment conducted by (Durukan *et al.* 2019), the highest P and K contents of tomato plants were increased by 40% vermicompost application (Durukan *et al.*, 2019).

Microelement concentrations of seedlings

Microelements are also important for the production of quality seedlings. The T1 and T2 treatments had the highest levels of Fe and Cu minerals in pepper seedlings, while the highest concentration of Mn was found in the T2, T4 and T1 treatments (Table 7). The T2 treatment had the highest level of Zn. In the of cauliflower seedlings, the vermicompost treatments showed a general increase in microelement contents.

Table 7. Effects of vermicompost treatments on micro mineral concentrations in pepper and cauliflower seedlings

Pepper	T1-(C)	T2	T3	T4
Fe	143.35 ± 3.95* ab	181.60 ± 34.53 a	104.65 ± 4.47 b	120.90 ± 10.57 b
Mn	60.20 ± 5.31 a	64.40 ± 0.29 a	45.80 ± 2.77 b	60.45 ± 1.41 a
Zn	20.15 ± 0.95 b	63.15 ± 13.13 a	32.70 ± 0.29 b	39.15 ± 0.49 b
Cu	580.85 ± 37.61 ab	686.20 ± 24.77 a	457.55 ± 75.72 b	491.95 ± 27.45 b
Cauliflower				
Fe	84.65 ± 0.38 b	111.80 ± 6.47 a	106.00 ± 5.89 a	102.65 ± 7.88 ab
Mn	46.55 ± 1.99 bc	42.05 ± 0.66 c	55.10 ± 0.64 a	50.96 ± 2.05 ab
Zn	14.30 ± 1.04 b	20.45 ± 0.32 a	22.40 ± 0.75 a	22.00 ± 1.10 a
Cu	262.40 ± 4.21 b	320.60 ± 20.96 ab	366.10 ± 33.43 a	304.20 ± 20.73 ab

Data are shown as the mean.
* ± standard error, different letters indicate a difference between treatments ($p < 0.05$).

There are similar and different research results regarding the impact of vermicompost on microelements. For instance, Hernández *et al*. (2010) demonstrated that changes in vermicompost dose did not affect the Fe and Zn contents of tomato seedlings, although other microelements were significantly impacted. They also found that the use of vermicompost increased Fe, Zn and Cu contents in lettuce. In another experiment, Kabay (2023) found that combining vermicompost with soil resulted in increased Fe and Zn concentrations in spinach. Additionally, Tuğa *et al*. (2021) reported that vermicompost elevated the Zn and Cu contents of lettuce.

Some studies have indicated that vermicompost application positively impacts micronutrient uptake, such as Fe (Hashemimajd *et al*., 2004; Sönmez *et al*., 2011), Zn (Azarmi *et al*., 2008). However, Teke *et al*. (2019) observed no effect on microelement contents in tomatoes. On the other hand, Durukan *et al*. (2019) established that the solid form of vermicompost application on tomatoes had a more significant effect on Fe and Zn contents, while liquid vermicompost application had a significant influence only on the Mn concentration. But no difference was found for Cu. According to Maltaş *et al*. (2017), the levels of Fe, Zn and Mn elements in red cabbage were sufficient with the application of vermicompost. In a study conducted under salt stress conditions, Demir and Kıran (2020) found that vermicompost applications led to a significant increase in microelement contents of cauliflower seedlings. It was observed that vermicompost applications increased Fe, Mn and Cu contents especially in cauliflower seedlings. As stated by Rangarajan *et al*. (2008), it can be said that vermicompost enriches the environment in terms of Fe and Mn thanks to the beneficial microorganisms it contains, and helps the enrichment of plants with microelements by secreting plant growth regulators in the rhizosphere.

Conclusions

Increasing yield and quality in vegetable production is closely related to seedling production. The choice of medium for quality seedling production is crucial. Peat is a widely used medium for seedling production worldwide. The production of seedlings for vegetables, which were previously grown from seed, is increasing the use of peat. However, due to the depletion of peat resources and its high cost, researches are exploring alternative media and mixtures to peat. This study investigated the effects of various peat and vermicompost mixtures on the growth, development, some quality characteristics, and macro-micro mineral concentrations of pepper and cauliflower seedlings. The mixtures applied had a significant influence on both vegetable species in terms of the criteria assessed. In conclusion, the T3 mixture and T2 mixture containing vermicompost instead of peat provided considerable superiority in the cultivation of pepper and cauliflower seedlings. These media are recommended as an alternative to T1 medium used in mass seedling production.

Authors' Contributions

Conceptualization: H.D.; Data curation: H.D., D.B.; Formal analysis: H.D.; Investigation: D.B., H.D.; Methodology: H.D.; Project administration: H.D., D.B.; Supervision: H.D.; Visualization: H.D., D.B.; Writing - original draft: H.D. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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