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Use of Vermicompost from Sugar Beet Pulp in Cultivation of Peas (*Pisum sativum* L.)

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Abstract: A properly conducted vermicomposting process is an environmentally friendly technology used to transform selected organic waste into vermicompost. This organic fertilizer is increasingly used in agriculture and horticulture as an alternative to mineral fertilizers. Research has investigated the use of vermicompost made from the waste mass of sugar beet pulp as a soil additive in the cultivation of peas (*Pisum sativum* L.). Experimentally, five treatments consisted of: a heavy clay soil as control (SL); the same soil with 10, 25, and 50% substitution of vermicompost, (V10, V25, and V50, respectively); and a standard peat-based horticulture substrate (GS) for comparison. Analyzed pea characteristics and the content of macro and microelements in their biomass were most favorably influenced by 25 and 50% vermicompost addition, and the values obtained were similar to those in the GS treatment. The lowest values of analyzed traits for *P. sativum* were found in the SL group. Thus, appropriate addition of vermicompost in the construction of plant growing substrates can reduce the use of inorganic fertilizers and be an alternative to peat in the medium, contributing to reduced use of this valuable environmental resource.

Keywords: vermicompost; *P. sativum*; growing medium; plant nutrients; plant growth

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Citation: Pączka, G.; Mazur-Pączka, A.; Garczyńska, M.; Hajduk, E.; Kostecka, J.; Bartkowska, I.; Butt, K.R. Use of Vermicompost from Sugar Beet Pulp in Cultivation of Peas (*Pisum sativum* L.). *Agriculture* **2021**, *11*, 919. https://doi.org/10.3390/agriculture11100919

Academic Editor: Nguyen V. Hue

Received: 12 August 2021
Accepted: 23 September 2021
Published: 25 September 2021

1. Introduction

One of the main pillars of sustainable agriculture, a set of practices that protect environmental resources without reducing human needs, is maximizing the use of organic fertilizers in plant production and preventing degradation of soil ecosystems [1]. Available information suggests that soil degradation has increased significantly in recent decades [2], with many EU soils characterized by a significant reduction in fertility, which directly affects crop quantity and quality. Unfavorable processes will continue if appropriate action is not taken [3]. Moreover, small farms and horticultural practices tend to produce nursery material in small containers, where peat is a major component [4]. Peat is used to ensure adequate aeration and hydration in the rhizosphere and maintain an appropriate level of nutrients for plant growth and development [5]. However, peat is a non-renewable environmental resource, and its consumption causes the exploitation and degradation of valuable and endangered ecosystems [6]. Research is currently investigating the use of alternatives to peat in growing media [7], of which one is organic waste produced in rural areas, which contains significant amounts of nutrients for plants. Nevertheless, careful processing and application are required to avoid deterioration of soil fertility and phytotoxic effects.

The use of non-stabilized organic waste may limit the development of specific groups of microorganisms, which, in turn, may significantly delay waste decomposition and mineralization [8]. One method of converting waste organic mass is vermicomposting, which is becoming more popular due to its potentially low environmental burden [9] and a growing awareness that organic waste is a source of nutrients and its application plays an essential role in improving soil quality and the restoration of biodiversity [10]. Vermicomposting accelerates the conversion of waste organic matter into nutrient-abundant vermicompost through the interaction of a dense population of earthworms and microorganisms [11]. Vermicomposting takes place at temperatures lower than 35 °C [12,13]. The optimal range is 20 to 25 °C, with a substrate humidity in the range of 70–75% and a pH of 6.8–8.0 [14,15]. The pH changes in the vermicomposting process are probably caused by the mineralization of nitrogen and phosphorus to nitrates and orthophosphates and the production of organic acids [13].

Vermicompost has a fragmented structure with high porosity, which promotes good aeration and water retention capacity, and contains nitrates, phosphorus, potassium, calcium, and magnesium, largely in forms easily available to plants [16]. Vermicomposts are also a source of phytohormones such as auxins, gibberellins, and cytokines, and therefore, have great potential for maintaining soil fertility [17,18]. The positive effect of vermicompost on the growth and development of strawberries was demonstrated by Arancon et al. [19] and Singh et al. [20]; Atiyeh et al. [21] and Zaller [22] showed stimulated germination, growth, and fruiting of tomatoes. According to Bachman and Metzger [23], a 10% addition of vermicompost to a substrate increased the surface area of marigold, tomato, green pepper, and cornflower leaves compared to plants growing in the substrate without addition. Vermicompost has also been shown to positively affect the length, weight, and number of shoots of *Vinca rosea* and *Oryza sativa* [24].

The aim of the current study was to assess the possibility of using vermicompost produced from waste mass of sugar beet pulp as a plant nutrient-rich additive to mineral soil in the cultivation of peas (*P. sativum* L.). Specific objectives were to: (i) Measure above and below ground growth and mass production; (ii) record the number of flowers and pods produced; (iii) determine the number and mass of seeds produced; (iv) record the level of root nodulation; (v) assess the chemical nature of the growth media used and of the waste organic matter produced.

2. Materials and Methods

2.1. Production of Vermicompost from Sugar Beet Pulp

Vermicompost was produced in vermireactors constructed of plastic boxes with dimensions of 600 × 300 × 300 mm (length × width × height), following the methodology proposed by Pączka et al. [25]. The base of each was pierced with small holes to drain excess water. Each vermireactor was placed in a larger box so that the bases were not touching (a gap of 30 mm) to store excess water. Vegetable waste in the form of sugar beet pulp was placed into the prepared vermireactors, and only sexually mature *Eisenia fetida* earthworms (with an initial density of 5 ind. dm^{-3} of waste) were introduced. The vermireactors were secured from above with a nylon mesh, which prevented the earthworms from escaping, and with cardboard, which prevented the soil from drying out. The vermicomposting process was carried out in an air-conditioned chamber at a temperature of 20 ± 0.5 °C. To maintain adequate humidity inside the vermireactors, they were moistened with tap water every ten days.

2.2. Experimental Design

The influence of the produced vermicompost on selected features of *P. sativum* plants was investigated in a pot experiment. The plant material for the research was qualified (EC qualification level) pea seeds of the "Iłówiecki" cultivar by W. Legutko (Przedsiębiorstwo Hodowlano-Nasienne Sp. z o.o.), purchased in retail sale. Five treatments were established:

GS—Kronen peat-based vegetable growing substrate;

SL—agricultural soil;
V10—10% of vermicompost + 90% of SL;
V25—25% of vermicompost + 75% of SL;
V50—50% of vermicompost + 50% of SL.

The control substrate (SL) was soil collected from agricultural land intended for plant production, located near the city of Tyczyn (southeast Poland). The soil was classified as heavy clay (fraction content <0.02 mm, 37.9%) [26]. As a substrate in the GS group, Kronen's balanced horticultural soil based on peat was used, having a composition of: high moor peat, low moor peat, pearlite, sand, microelements, mineral fertilizer NPK. Vermicompost from the waste mass of sugar beet pulp was produced at the Institute of Agricultural Sciences, Land Management and Environmental Protection, University of Rzeszów. The macro and micronutrient contents of this medium are presented in Table 1.

Table 1. The content of macronutrients and microelements in the given growth media—details in text (mean ± standard deviation based on five samples).

Parameter	Units	Garden Substrate (GS)	Soil (SL)	Vermicompost	V10	V25	V50
C	$mg\ kg^{-1}$ (d.m.)	22,394.1 ± 1889.6a	5250.2 ± 76.1b	97,774.3 ± 2483.9c	14,533.6 ± 526.3d	28,420.7 ± 614.9e	51,571.8 ± 711.7f
N		1280.4 ± 53.5a	808.2 ± 21.3b	4899.1 ± 51.8c	1217.3 ± 24.2a	1830.9 ± 27.9d	2853.7 ± 29.6e
P		207.7 ± 38.1a	74.8 ± 7.5b	288.7 ± 22.7c	96.6 ± 8.2d	129.5 ± 9.6e	180.4 ± 9.9f
K		684.2 ± 39.5a	114.8 ± 29.3b	3588.1 ± 55.8c	465.4 ± 19.9d	984.5 ± 21.1e	1853.6 ± 18.1f
Ca		2245.9 ± 81.3a	704.8 ± 27.1b	1950.3 ± 77.1c	828.7 ± 14.5d	1017.6 ± 21.1e	1339.0 ± 19.2f
Mg		359.4 ± 42.6a	91.5 ± 10.4b	274.4 ± 33.2c	112.8 ± 11.3d	137.5 ± 14.1e	188.8 ± 17.5f
Cu		31.7 ± 9.9a	11.4 ± 2.2b	45.1 ± 4.4c	14.8 ± 2.6d	19.8 ± 1.9e	28.3 ± 2.2a
Mn		288.1 ± 19.7a	522.9 ± 18.1b	396.3 ± 22.1c	510.2 ± 11.4b	491.3 ± 9.9b	459.6 ± 10.6bc
Zn		68.6 ± 11.4a	69.5 ± 9.4a	53.3 ± 8.9b	67.9 ± 5.3a	65.5 ± 4.1a	61.4 ± 4.2a
Cd		1.7 ± 0.2a	1.1 ± 0.1b	0.9 ± 0.1c	1.1 ± 0.1b	1.1 ± 0.1b	1.0 ± 0.1b
Pb		1.9 ± 0.2a	14.4 ± 2.8b	0.6 ± 0.1c	13.0 ± 0.4b	11.0 ± 0.2d	7.5 ± 0.2e
C/N ratio	—	17.50 ± 1.1a	6.50 ± 0.4b	19.96 ± 1.33a	7.85 ± 0.3c	9.87 ± 0.5d	13.23 ± 0.7e
pH in H_2O	—	6.40 ± 0.41	6.28 ± 0.27	6.29 ± 0.11	6.28 ± 0.17	6.28 ± 0.09	6.29 ± 0.12
Electrical conductivity	$mS \cdot cm^{-1}$	1.4 ± 0.17a	0.19 ± 0.002b	2.37 ± 0.09c	0.72 ± 0.01d	1.31 ± 0.04a	1.86 ± 0.06e

Mean values in the same row followed by different letters are statistically different ($p < 0.05$).

Plastic pots, 30 cm in diameter and 40 cm high, were filled with the appropriate treatment substrate, to a depth of 37 cm. Then, eight pea seeds were planted and covered with a 3 cm layer of the same substrate (N = 5 replicated pots per treatment). The growing plants were watered simultaneously, evenly as needed, keeping the substrate moisture constant. The experiment was carried out in greenhouse conditions with natural sunlight from April 1 to June 20, 2020 (80 days). The mean temperature inside the greenhouse was: April—13 ± 2 °C; May—15 ± 2 °C; June—20 ± 2 °C.

During the research period, seedling emergence was recorded. After termination of the experiment, all plants were extracted and washed clean of the substrate, under running water, and after drying on filter paper, the whole plant and subdivisions of their aerial and root parts were measured and weighed. Mean number of flowers, weight of pods, and number of root nodules were determined (all per plant). Then, plant shoots devoid of pods were subjected to physicochemical analysis to investigate the influence of the applied substrates on the content of selected macro and microelements in *P. sativum* biomass.

2.3. Physicochemical Analysis of Substrates and Plant Material

The total content of macronutrients (N, P, K, Ca, Mg) and microelements (Cu, Mn, Zn, Cd, Pb) was determined in the growing media and plant material using the procedures described by Ostrowska et al. [27]. Nitrogen was determined by the Kjeldahl method using Kjeltec 8100 and 2006 Foss Tecator Digestor apparatus. To determine the remaining elements, the organic research material was subjected to hot mineralization at 210 °C in an open system, in a mixture of concentrated mineral acids HNO_3:$HClO_4$:H_2SO_4 in the ratio 20:5:1 [27] (the soil was mineralized in pure concentrated $HClO_4$). In the solution obtained after mineralization, phosphorus was determined colorimetrically by the vanadium-molybdenum method on a Shimadzu UV-2600 spectrophotometer, while potassium, magnesium, calcium, and microelements and trace elements—by atomic absorption spectrophotometry using Hitachi Z-2000 [26]. Carbon was determined using a Vario EL-CUBE elemental analyzer (from Elementar Analysensysteme GmbH). The pH of the soil substrates was determined with the potentiometric method, with the soil:water ratio being 1:2.5. The salt concentration was determined by the conductometric method [28]. The C/N ratio was calculated in the analyzed media and plant biomass.

2.4. Statistical Analysis

All statistical analyses were expressed as the mean of five replicates using the computer software package Statistica 13.1. Tukey's t-test was used as a post hoc analysis to compare the means. One-way analysis of variance (ANOVA) was used to analyze the significant difference between different research groups for the observed monitoring parameters and the significant difference between macro and microelement contents in research groups.

3. Results and Discussion

3.1. Analysis of Selected Features of P. sativum Depending on the Growing Substrate Used

As shown, the addition of vermicompost to arable soil (SL) positively influenced *P. sativum* (Table 2).

Table 2. Selected plant features for the given treatment growth media (as in Table 1) (mean ± standard deviation based on five replicates).

a)

Growth Media	Seed Emergence [%]	Mean Stalk length [cm]	Mean Stalk mass [g]	Mean Root length [cm]	Mean Root mass [g]	Mean Nodules Number [Per Plant]
GS	100a	67.8 ± 0.76a	45.68 ± 0.63a	22.1 ± 0.54a	5.11 ± 0.12a	6.3 ± 0.76a
SL	76b	41.3 ± 0.83b	19.96 ± 0.46b	16.9 ± 0.58b	2.56 ± 0.23b	3.9 ± 0.48b
V10	92a	54.8 ± 1.31c	31.44 ± 1.46c	20.3 ± 1.28a	4.81 ± 0.07a	5.9 ± 0.79a
V25	100a	68.2 ± 0.86a	47.94 ± 0.69a	21.4 ± 0.89a	5.06 ± 0.11a	6.4 ± 0.24a
V50	96a	68.1 ± 1.05a	47.02 ± 0.99a	21.5 ± 1.04a	4.96 ± 0.29a	6.5 ± 0.47a

b)

Growth Media	Mean Flowers Number [Per Plant]	Mean Pod Number [Per Plant]	Mean Pod Mass [g]	Mean Seed Number in Pod	Mean Sum of Seed Biomass in Pod [g]	Growth Media
GS	10.6 ± 0.84a	9.4 ± 0.89a	4.72 ± 0.46	6.14 ± 0.69	2.51 ± 0.35	GS
SL	6.6 ± 0.89b	5.4 ± 0.56b	4.44 ± 0.59	6.02 ± 0.39	2.40 ± 0.28	SL
V10	9.2 ± 0.55a	7.8 ± 0.84c	4.54 ± 0.53	6.02 ± 0.25	2.46 ± 0.32	V10
V25	11.6 ± 0.80a	10.4 ± 0.55a	4.56 ± 0.73	6.36 ± 0.84	2.58 ± 0.21	V25
V50	11.4 ± 1.34a	10.2 ± 1.31a	4.67 ± 0.86	6.38 ± 0.62	2.55 ± 0.29	V50

Mean values in the same column followed by different letters are statistically different ($p < 0.05$).

The best results for plant emergence were for V25, where 100% was obtained (a similar result to the GS treatment). Equally high emergence was found in V10 and V50, with a significant difference between the control group SL (76% seedling emergence) and all other treatments ($p < 0.05$). Primary plant growth processes are crucial because they significantly affect further plant development and potential yield [29]. Water is vital to the emergence of plants, but excess or a deficiency can cause problems. Disorders in water management, to which crops are most often exposed, inhibit many physiological and biochemical processes, including reduced photosynthesis and damage to chlorophyll, leading to reduced plant growth [30,31]. In the present study, such problems were present in the SL control, which was a heavy clay soil.

Greatest mean length and weight of stalks were found in V25 (68.2 ± 0.86 cm and 47.94 ± 0.69 g, respectively) and V50 (68.1 ± 1.05 cm and 47.02 ± 0.99 g, respectively), similar to the GS group (67.8 ± 0.76 cm and 45.68 ± 0.63 g, respectively). These were not statistically different ($p > 0.05$), but significant differences ($p < 0.05$) were shown between the V25, V50, GS treatments and V10 (54.8 ± 1.31 cm and 31.44 ± 1.46 g, respectively) and control (SL) (41.3 ± 0.83 cm and 19.96 ± 0.46 g) (Table 2). Paul and Metzger [32] showed that a 20% addition of vermicompost to the growing substrate had a positive effect on selected tomato characteristics, including plant height, leaf area, and root system compared to a control group. In turn, Gutierrez-Miceli et al. [33] showed that the additions of vermicompost to soil in the ratio of 1:3 and 1:4 had a positive effect on the height of plants and the number of tomato leaves.

From mean length and weight of *P. sativum* roots, it was found that plants growing in a substrate with the addition of vermicompost were characterized by similar values, which were also similar to those grown in GS commercial substrate (Table 2). Mean length and weight of roots in the SL treatment were lower than in the other groups (by 16.8–23.5% and 46.8–49.9%, respectively; $p < 0.05$).

In the SL treatment, there was also a significantly lower mean number of root nodules (3.9 ± 0.48 per plant) compared to the other treatments; where values were similar, all of these were higher than SL by an average of 38% ($p < 0.05$) (Table 2). It has been shown that the addition of vermicompost rich in humic acid stimulates the development of root nodules in *P. sativum*. Vermicompost also had a positive effect on the diversity and density of soil microbes [34]. For example, endophytic bacteria that live in the nodule tissue promote plant growth by producing growth-promoting substances. Moreover, these bacteria act synergistically with rhizobiasis, improving nodulation and nitrogen fixation [35]. The relationship between the growth of roots and root nodules is not fully known. It is known that plants that use almost exclusively symbiotic N_2 fixing are characterized by a lower root system mass but have more root nodules than plants fed with plant-available nitrogen forms, which do not have a symbiotic N_2 fixing system [36,37]. Such information does not coincide with the results of this study because plants from the SL group produced the lowest average number of root nodules as well as the shortest and lightest roots (Table 2). Bahadur and Manohar [38] showed that biofertilizers in pea cultivation contribute to an increase in the number of root nodules. Intensity of root nodule development may be related to the total growth of plants and depend on various environmental factors such as water stress, salinity, or the availability of nitrates [39].

The addition of vermicompost to heavy soil positively influenced the average number of flowers and pods. Similar high values ($p > 0.05$) were achieved by plants from V25 and V50 treatments, where an average of 74% ($p < 0.05$) of flowers and 91% ($p < 0.05$) of pods were obtained compared to the SL control group (Table 2). Wiatr [40] states that the minimum number of pods per plant that would provide a satisfactory yield should not be less than 10. In the present study, in V25 and V50 treatments, 10.4 ± 0.55 and 10.2 ± 1.31 pods per plant were obtained, respectively. When examining the effect of vermicompost produced from cattle manure and municipal waste on selected characteristics of a petunia, Arancon et al. [41] observed that 30–40% vermicompost addition produced the highest number of flowers, and higher doses led to a reduction in flowering. In the current work, no significant differences were found between the treatments in mean weight of pods, mean number of seeds per pod, and the mean sum of seed biomass per pod (Table 2).

Significant differences in the development of the aboveground and belowground parts of *P. sativum* plants growing in the control medium (SL) and the remaining treatments could be caused by various factors. One may be a significantly lower phosphorus content in the SL group compared to the other media (difference 22.6–64.0%; $p < 0.05$) (Table 1). *P. sativum* is a legume plant that can fix atmospheric nitrogen with papillary bacteria of the genus *Rhizobium* due to symbiosis. However, nitrogen-fixing bacteria require a lot of energy, not only for their growth but also for converting N_2 to NH_3. Rotaru and Sinclair [42] reported that phosphorus provides a large amount of energy to N_2-fixing bacteria. According to Saeed et al. [43], higher phosphorus content in the soil increases the availability of nitrogen and potassium, which improves plant growth. Phosphorus effectively contributes to the growth of aboveground parts of plants, develops the root system, initiates flowering, and develops seeds and fruits [44]. Therefore, plant production on about 30% of the world's agricultural land is limited by phosphorus availability [45]. In addition, phosphorus has an enhancing effect on plant growth and yield [46]. Graham and Rosas [47] found that phosphorus deficiency reduced nitrogen fixation, which reduced the growth and yield of peas. As reported by Kumar [48], increasing doses of phosphorus (from 0 to 60 kg ha^{-1}) provided higher values of *P. sativum* such as plant height and weight, number of root nodules, and number of pods and seeds per pod. Similar observations were made by Iqbal et al. [49] in the cultivation of mung beans (*Vigna radiata*). Kumar [48] showed that the increase in selected features of *P. sativum* plants resulted from the application of increasing doses of phosphorus, as it plays an essential role in photosynthesis, respiration, and fat metabolism. Garg et al. [50] and Jin et al. [51] showed that phosphorus increased the mass of the soybean root system in the seedling phase, which accelerated the full maturity of the plants.

Potassium is also vital for ensuring optimal plant growth [52], with the content of this element being 4–16 times higher in vermicompost addition and GS treatments compared with the SL control (Table 1). Potassium plays an important role, e.g., in protein synthesis, sugar transport and photosynthesis. It is also essential for cell growth—a critical process for plant development and function [53]—and plays an essential role in improving crop quality [54]. Although high concentrations of K in the soil solution may inhibit uptake of Mg, and thus, cause a deficiency of this element in plants [55], a deficiency of K may disturb some processes necessary for plant development [56]. It should also be noted that K influences the utilization of other nutrients by plants, and the need for K depends on the cultivated plants and other biotic and abiotic factors. Akter et al. [57], in research on the effect of different doses of K on selected characteristics of *P. sativum*, showed that the use of K at a dose of 50 kg ha^{-1} had a positive effect on plant length and number of flowers and pods compared to doses of 25 and 75 kg ha^{-1}.

The soil itself may also be important. Heavy clay soils are difficult to cultivate because they have numerous limitations, especially in dry areas and with medium and heavy rainfall [58]. Plants grown in these soils have a less developed root system, and hence, difficulties with water uptake. These soils have a compact structure, often disturbed water–air balance, and may show signs of hypoxia, and on slopes, runoff may lead to water losses, and temporarily, flooding can appear on the flat [59].

As reported by Alvino and Leone [60] in Italy, Spain, and France, the most common factor limiting the development of *P. sativum* is high air temperature, leading to water deficit, excessive weed infestation, and insufficient plant density. Księżak [61] and Borowiecki et al. [62] suggest that the optimal plant density of *P. sativum* should be within 60–125 plants m^{-2}. In the current research, plant density was within these limits (approx. 113 plants m^{-2}), while other harmful factors for pea growth, mentioned above, were avoided.

Compared to SL control, higher values for some features of *P. sativum* growing on media with 25 and 50% vermicompost can potentially be attributed to a more significant amount and availability of nutrients, and the increased activity of microorganisms. It is also well known that during the vermicomposting process, some microorganisms such as bacteria, fungi, and algae can produce plant phytohormones such as auxins, gibberellins, and cytokines, which may have a positive effect on plant growth [63].

3.2. Impact of Growing Media on Selected Macronutrients and Microelements in the Biomass of P. sativum Stalks

In this study, it was considered justified to analyze the aboveground parts (stalks) of *P. sativum* plants, to determine whether the added vermicomposts led to significant differences in nutrients affecting future use of the material for the potential production of further vermicomposts. We believe that this is a vital issue in terms of promoting the concept of a circular economy. In the agricultural sector, this concept assumes the use of innovative technologies in the field of pro-environmental management of agricultural waste as valuable raw materials containing, for example, a wealth of nutrients for crops. According to Winkler [64], the development of a circular economy requires introducing closed-loop systems to work towards environmental, social, and economic sustainability. The development of such systems aims to replace traditional linear production models aimed at deriving goods from natural resources to produce products and ultimately waste [65].

As shown in this study, a similar ($p > 0.05$) high nitrogen content in pea stalks was found in V25, V50 and GS, while the lowest was in SL and V10 (Table 3). The most considerable difference (15%; $p < 0.05$) was found between plants from the V50 group (28,871.4 ± 36.9 mg kg^{-1}) and *P. sativum* growing in the SL medium (24,721.3 ± 74.7 mg kg^{-1}) (Table 3). This could result from the differences in the content of N in the growing substrate and the differences in the mean number of root nodules produced. Because plants that draw nitrogen as a result of symbiosis with papillary bacteria have a smaller mass of the root system, but more root nodules [36,37] and that plants from the SL group had significantly shorter roots, with a significantly lower mass, with the lowest average number of produced root nodules (Table 2), it can be concluded that nitrogen extraction from the soil with the lowest N content could predominate (Table 1).

Table 3. Contents of macro and microelements in biomass of *P. sativum* stalks (mean ± standard deviation based on five replicates).

Parameter	Units	Garden Substrate (GS)	Soil (SL)	V10	V25	V50
N	mg kg^{-1}(d.m.)	27,867.4 ± 28.7a	24,721.3 ± 74.7b	25,932.3 ± 39.1b	28,244.1 ± 45.7a	28,871.4 ± 36.9a
P		5427.2 ± 17.2a	3840.3 ± 22.6b	4416.9 ± 22.3b	5498.3 ± 18.4a	5644.7 ± 26.3a
K		25,335.2 ± 18.4a	20,811.7 ± 45.2b	22,040.2 ± 27.5b	25,615.1 ± 34.5a	26,253.8 ± 51.7a
Ca		24,818.5 ± 26.6a	19,921.1 ± 39.7b	20,101.6 ± 33.4b	23,233.5 ± 29.2a	24,202.1 ± 32.6a
Mg		2471.1 ± 18.6a	1654.4 ± 16.5b	1714.7 ± 17.2b	2113.3 ± 24.8c	2201.1 ± 19.7c
Cu		3.8 ± 0.1a	2.6 ± 0.1b	2.8 ± 0.2b	3.6 ± 0.3a	3.7 ± 0.2a
Mn		32.4 ± 7.2	34.2 ± 9.6	35.7 ± 6.9	35.1 ± 6.3	34.4 ± 3.9
Zn		42.1 ± 4.7	41.5 ± 8.3	41.8 ± 6.4	41.6 ± 5.7	40.8 ± 5.1
Cd		0.6 ± 0.1a	0.5 ± 0.1ab	0.4 ± 0.1b	0.4 ± 0.1b	0.5 ± 0.1ab
Pb		1.13 ± 0.1a	2.88 ± 0.2b	2.91 ± 0.1b	2.08 ± 0.1c	1.89 ± 0.1c
pH in H_2O	—	7.76 ± 0.03	7.56 ± 0.03	7.61 ± 0.04	7.64 ± 0.02	7.65 ± 0.03

Values followed by different letters in the same row are statistically different ($p < 0.05$).

SL treatment plants also had the lowest phosphorus content in their biomass (Table 3) and growing substrate (Table 1), and as reported by Saeed et al. [43], higher phosphorus content in soil increases nitrogen availability for plants. Windsor and Adams [66] reported that the optimal content of N in the weight of plants should be from 39.0 to 50.0 g kg^{-1}. According to Lawlor et al. [67], if the supply of nitrogen exceeds the amount required to maintain the potential growth rate, then N may be accumulated in unproductive plant components or increase the yielding potential; however, it is often associated with a loss in the size and quality of seeds or fruits.

The current research also showed differences in the content of P, K, Ca, Mg, and Cu between the treatments, where the highest values of these elements were found in V25 V50 and GS (Table 3). According to Ates et al. [68], the content of macro and micronutrients in plants depends on soil parameters, its elements, fertilization and climatic conditions. Tekeli et al. [69] report that appropriate K, Ca, and Mg contents in properly developing forage plants are usually, 1.4–2.5%, 0.8–3.0%, and 0.2–12%, respectively. In the present study, the content of K and Ca in all treatments plants was within these ranges. Only the content of Mg in the biomass of plants growing in SL or V10 was below the presented range and amounted to 1654.4 ± 16.5 and 1714.7 ± 17.2 mg kg^{-1}, respectively. On the other hand, Ates [70] obtained 1.67% K, 1.63% Ca, 0.44% Mg, and 0.28% P content in field peas. It has also been shown that the K content in various wild plant species can range from 0.96 to 5.44% [71].

According to Amarakoon et al. [72], the content of magnesium and zinc in various genotypes of *P. sativum* cultivated in North Dakota (USA) was 1350 mg kg^{-1} for Mg and from 39 to 63 mg kg^{-1} for Zn. In the current study, the highest magnesium content in pea biomass was found from GS (2471.1 ± 18.6 mg kg^{-1}), but V25 and V50 also contributed to an increase in Mg content (2113.3 ± 24.8 mg kg^{-1} and 2201.1 ± 19.7 mg kg^{-1}, respectively) compared to the SL control group (Table 3). According to Amarakoon et al. [72], peas are a good source of Zn and Mg but a poor source of Ca (622–1219 mg kg^{-1}). In the current work, the Ca content in *P. sativum* biomass was much higher. In the V25 and V50 treatments, the Ca content was 23,233.5 ± 29.2 and 24,202.1 ± 32.6 mg kg^{-1}, respectively, and was significantly higher ($p < 0.05$) compared to the SL control group (19,921.1 ± 39.7 mg kg^{-1}) (Table 3).

Significant differences in the content of Cu and Pb between the V25 and V50 treatment and the SL control were also found in *P. sativum* biomass (Table 3). The lowest Cu content was observed in plants from the SL treatment (2.6 ± 0.1 mg kg^{-1}); the value was lower than for V25 and V50 by an average of 28.8% ($p < 0.05$), which could be related to the lowest content of this element in the soil (11.4 ± 2.2 mg kg^{-1})—less than V25 and V50 by 42% and 60%, respectively ($p < 0.05$) (Table 1). On the other hand, plants grown in soil without the addition of vermicompost were characterized by a higher content of Pb (2.88 ± 0.2 mg kg^{-1}) compared to plants growing in V25 (2.08 ± 0.1 mg kg^{-1}) and V50 (1.89 ± 0.1 mg kg^{-1}) (difference by 27.8% and 34.4%, respectively) ($p < 0.05$; Table 3). This regularity could be dictated by the higher content of this element in the heavy SL soil (Table 1).

According to Singh and Kalamdhad [73], Mn is necessary for proper development of plants, while a high content of this element in the soil may be toxic. In this study, no significant differences were found in the content of Mn in the biomass of pea plants between the treatments (Table 3). This element, at the pH of the substrate below 5.5, may cause damage to the assimilation apparatus that is dangerous for plants [74]. Conversely, lead is considered a poison that causes the underdevelopment of plants by inhibiting root growth and chlorosis. It also inhibits photosynthesis, lowers mineral nutrition, water balance, and enzyme activity [75]. The high lead content in soil causes a decrease in crop productivity, thus creating a severe problem for agriculture [76]. However, Blaylock et al. [77] reported that in a cultivation substrate with a pH between 5.5 and 7.5, Pb is not available much to plants, even if they have the genetic ability to accumulate it.

4. Conclusions

From this study, it can be concluded that: (1) Optimal addition to soil of vermicompost from the waste mass of sugar beet pulp is at 25% (V25). The admixture of vermicompost in such an amount allowed achievement of values not dissimilar ($p > 0.05$) to where 50% addition was applied. (2) Significant differences ($p < 0.05$) between groups V25 and V10 were found in terms of the average length and weight of stems and the average number of flowers and pods (in favor of the V25 group). (3) V25 addition to clay soil led to plants obtained with similarities to the GS group, where a peat-based substrate dedicated to vegetable cultivation was used. (4) *P. sativum* stalks grown in V25, and V50 predispose this plant biomass to be reprocessed into further vermicompost. (5) Vermicompost can be used successfully for plant cultivation and to improve soil structure. (6) Appropriate addition of sugar beet pulp vermicompost may replace the use of inorganic fertilizers and constitute an alternative to peat in the construction of growing substrates, contributing to a reduction in the use of this valuable environmental resource.

Author Contributions: Conceptualization, G.P.; methodology, G.P.; investigation, G.P., A.M.-P., M.G., E.H., J.K., K.R.B.; data curation, A.M.-P. and M.G.; writing—original draft preparation, G.P.; writing—review and editing, G.P., J.K., I.B. and K.R.B.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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