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Cow Manure Vermicomposting and an Initial Assessment of the Vermicompost Effect on the Production of Greenhouse Organic Crop Vegetables Under the Frame of Circular Economy

Research Article

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Abstract

During the process of vermicomposting organic residues are broken down by earthworms and microorganisms, thus promoting germination, growth and yields of plants. This research aimed to study vermicomposted cow manure in order to be used as soil amendment for the production of organic early crops vegetables, in the light of sustainable development and circular economy. In the context of the study, earthworms initially composted the mixture of cow manure and straw, while chemical and microbiological composition of the produced vermicompost was determined and assessed. Afterwards, an experiment was carried out in order; a) to investigate the effects of cow manure vermicompost application on the chemical and microbial properties of greenhouse soil of the Green Unit of the Psychiatric Hospital of Thessaloniki and b) to relate these properties to growth responses and crop production of organic early crops vegetables cultivated in the greenhouse. The crops used for the experiment were *Eruca sativa, Eruca vesicaria*, parsley, celery and dill that were grown in vermicomposted soil of the greenhouse. Two vermicompost applications after sowing took place and one or two harvests as well. For all the five crops cultivated in the greenhouse, growth height was regularly monitored in order to calculate the corresponding growth rates. Furthermore, foliar diagnosis was performed for every crop. The results showed positive effect on growth rates of all five crops, indicating significant contribution of vermicomposting to the enhancement of crop production.

Keywords: Vermicomposting; Cow manure; Circular economy; Organic crop vegetables; Greenhouse

Introduction

Organic materials are one of the major pillars of soil fertility, while they improve soil physical structure and nutrient availability in order to increase agricultural production, help to maintain the yield and quality, and are less costly than synthetic fertilizers [1]. A lot of researches have already reported beneficial uses of organic matter due to the presence of plant growth nutrients [2,3]. Land productivity and growth of different plant parameters are increased considerably with the addition of agricultural wastes, animal manure, compost and vermicompost [4,5], since they consist main resources providing organic matter and they contain large quantities of nitrogen, potassium and phosphorus.

Composts retain most of their original nutrients and have reduced levels of organic contaminants, since they are degraded before their use. Thus, they can be applied to increase soil organic matter and nutrients, which can be released upon decomposition, to improve soil structure and increase cation exchange capacity. Furthermore, due to the rapid decomposition and high temperatures during composting procedure, an odor-free, homogenous, pathogen-free and easy-to-handle product is produced [6]. Vermicomposting is a non-thermophilic process related to composting, which can improve the beneficial utilization of organic wastes, by which organic materials are converted by earthworms and microorganisms into rich soil amendments with greatly increased microbial activity and nutrient availability [6]. Vermicomposts are materials with high water-holding capacity, drainage, porosity, and aeration [7]. Moreover, they provide strong adsorption and retention of nutrients, as well as more microsites for microbial decomposing organisms, due to their increased surface areas [8]. Furthermore, due to the production of organic acids and CO2 during microbial metabolism, vermicomposts usually show pH values near neutrality [9]. Additionally, the fact that they are rich in actinomycetes, bacteria and cellulose-degrading bacteria, and fungi proves that they have great biological properties [6].

Vermicomposting positive effects on plant germination growth and yields have been demonstrated in many greenhouse experiments [6], concerning many crops cultivation, such as lettuce [10], tomatoes [11,12], potatoes [13], peppers [14] and beans [15], as well as landscape and house hold plants [16], and herbs [1] cultivation. Among their upper chemical characteristics, vermicomposts and especially those derived from animal waste contain more mineral elements compared to commercial plant growth media, while it is observed that many of these elements such as nitrates, soluble potassium, calcium and magnesium, and exchangeable phosphorus are changed to forms that can be easily absorbed by plants [17].

A number of greenhouse experiments have reported positive effects of low application rates of vermicomposts to organic crops, including high growth rates and increased yields [6]. Torkashvand et al., found that the increased addition of cow manure compost in the cultivation bed of *Strelitzia reginae* compared with the inorganic fertilizers increased most growth characteristics of the plant [18]. Waleed S. Alwaneen reported that cow manure vermicompost application showed significant effect on plant height and fresh biomass of landscape and house hold plants [16].

The objective of this research was to evaluate vermicomposted cow manure in order to be used as soil amendment for the production of organic early crops vegetables, in the light of sustainable development and circular economy. In the context of the study, earthworms initially composted the mixture of cow manure and straw, while chemical and microbiological composition of the produced vermicompost was determined and assessed. Afterwards, an experiment was carried out in order; a) to investigate the effects of cow manure vermicompost application on the chemical and microbial properties of greenhouse soil of the Green Unit of the Psychiatric Hospital of Thessaloniki and b) to relate these properties to growth responses and crop production of organic early crops vegetables cultivated in the greenhouse. The crops used for the experiment were *Eruca sativa, Eruca vesicaria*, parsley, celery and dill that were grown in both vermicomposted soil and non-vermicomposted soil of the greenhouse.

Materials and Methods

Earthworms Compost Preparation

Recently-deposited cow manure was collected from a livestock unit in Evosmos, Thessaloniki. Approximately 9m^3 of the manure (organic matter 52%) was placed at the premises of Green Unit of Psychiatric Hospital of Thessaloniki. The manure was accumulated in a high pile and mixed with wheat straw suitable for animal feed that we procured from an agricultural land near the hospital, in order to adjust the C/N ratio. Since the initial C/N ratio of the manure was low (≈12), a sufficient amount of straw was added to increase the C/N ratio to 24, which is the lower value permitted for the composting process. However, the composting process was speeded up, while organic matter was already high (52%).

Cow manure was mixed twice a week and the temperature was monitored. Initially the temperature increased to 65^{o}C and was maintained at this value for seven days, while then it gradually decreased and stabilized at 45^{o}C. During these seven days the pathogens were destroyed and suitable sanitation conditions were created for the earthworms composting, during which the temperature remained lower than 30^{o}C, so that the earthworms do not die.

Then the pile with the compost was transferred and two rows of dimensions 3m × 2.5m × 0.5m (length, width, height) were formed on a concrete platform in another area of the premises of Green Unit of Psychiatric Hospital of Thessaloniki. The manure was transferred into containers and after two weeks they were vaccinated with earthworms. Sprinkler irrigation system was installed on the rows. The rows were irrigated twice a day for 30' and stirred twice a week with special shovels. Earthworms composting lasted 90 days and afterwards chemical analysis of the produced compost took place at the laboratory of Soil and Water Resources Institute (SWRI) of Hellenic Agricultural Organization 'DEMETER' in Sindos, Greece. Microbiological analysis also took place at the laboratory of Veterinary Research Institute of the National Agricultural Research Foundation (NAGREF) in Thessaloniki, Greece. Vermicompost main chemical and microbiological properties are summarized in Table 1.

Table 1: Main chemical and microbiological characteristics of vermicompost.

Parameter	Value	Parameter	Value
pH	7.3	P (mg kg^{-1})	478
Electrical Conductivity (μS cm^{-1})	3320	B (mg kg^{-1})	11.1
Organic Matter (%)	31.1	Fe (mg kg^{-1})	60
Organic Carbon (%)	15.05	Mn (mg kg-1)	18.5
Exchangable K (mg kg^{-1})	2800	Ni (mg kg^{-1})	1.59
Exchangable Ca (mg kg^{-1})	3943	Pb (mg kg^{-1})	2.38
Exchangable Mg (mg kg^{-1})	1990	Cd (mg kg^{-1})	0.252
N total (g kg^{-1})	33.1	*E. coli*	2.4*10^2/g
NO_3-N (mg kg^{-1})	56.6	*Salmonella sp.*	- / 25 g

Application of the Vermicompost in Organic Early Crops Vegetables

After three months the vermicomposted manure was used in organic early crop vegetables growth bioassays, to provide an index of maturity and utility of the organic waste. The crops used for the experiment were *Eruca sativa, Eruca vesicaria*, parsley, celery and dill that were grown in vermicomposted soil of the greenhouse. Two vermicompost applications (1 L/m^2 and 1.5 L/m^2) after sowing took place and one or two harvests after the applications as well. Crops were drip-irrigated daily with water. For all the five crops cultivated in the greenhouse, growth height was regularly monitored in order to calculate the corresponding growth rates. Furthermore, foliar diagnosis was performed for every crop.

Analytical Methods

pH was measured by a JENWAY 3520 pH Meter in water saturated soil paste for soil samples. Electrical conductivity was measured by a CRISON GLP 32 Conductometer in water saturated soil paste. Walkey-Black method was used for soil organic matter analysis [19], while Loss-On-Ignition Method was used for biomixture organic matter analysis [20]. $CaCO_3$ was measured with Automatic Digital Soil Calcimeter Fogl. Extractable phosphorus and boron were determined colorimetrically using a Perkin Elmer Lambda 35 UV/VIS spectrophotometer. Exchangeable K and Na were determined after extraction with ammonium acetate by Sherwood M410 Flame Photometer. Exchangeable Ca and Mg were determined after extraction with ammonium acetate with a Perkin Elmer AAnalyst 200 Atomic Absorption Spectrometer. Fe, Cu, Mn and Zn were measured after extraction with DTPA with a Perkin Elmer AAnalyst 200 Atomic Absorption Spectrometer. Total N was determined according to ISO 11261:1995 Soil quality – Determination of total nitrogen – Modified Kjeldahl Method [21]. NO_3- measurement was performed after extraction with KCl and by passage through a column of copperized cadmium, based on Methods of Soil Analysis – Part 3 – Chemical Methods, 1996, Chapter 38 Nitrogen – Inorganic Forms [22]. Soil texture analysis was performed according to Bouyoucos method [23].

Results and Discussion

Vermicompost application on greenhouse soil had positive effect regarding pH, organic matter and calcium carbonate, while nutrients (Mg, Fe, Mn, Zn, Cu, B) range at the same concentration levels. Concerning potassium, phosphorus and nitrates, their concentrations were slightly lower because organic fertilizer had been previously applied on soil.

According to the results presented in the Table 2, 40 days after sowing and 2 compost applications *Eruca sativa* grew by 18 cm, indicating a growth rate of 0.45 cm per day, while 48 days after sowing and 2 compost applications *Eruca sativa* grew by 23 cm, indicating a growth rate of 0.48 cm per day. Likewise, 55 days after sowing and 2 compost applications *Eruca sativa* grew by 30 cm, indicating a growth rate of 0.55 cm per day. It is recommended to harvest the *Eruca sativa* in 55-67 days to produce appropriate height plant, which is almost 30 cm height for commercial product of *Eruca sativa*. It is worth noting that 37 days after the 1st harvest eruca sativa height reached 23 cm, nominating a satisfactory growth rate of 0.62 cm per day.

Table 2: Growth monitoring of *Eruca sativa*.

Eruca sativa	Date	Height (cm)
sowing	21 November 2020	
stem	30 November 2020	
1st application of compost	1 December 2020	2.5
	7 December 2020	6
2nd application of compost	14 December 2020	8
	21 December 2020	10
	31 December 2020	18
	8 January 2021	23
1st harvest	15 January2021	30
2nd harvest	22 February 2021	23

According to the results presented in the Table 3, 60 days after sowing and 2 compost applications *Eruca vesicaria* grew by 15 cm, indicating a growth rate of 0.25 cm per day, while 67 days after sowing and 2 compost applications *Eruca vesicaria* grew by 20 cm, indicating a growth rate of 0.30 cm per day. It is recommended to harvest the Eruca vesicaria in 67-80 days to produce appropriate height plant, almost 20 cm height for commercial product of *Eruca vesicaria*. It is worth noting that 2 months after the 1st harvest *Eruca vesicaria* height reached 21 cm, nominating a satisfactory growth rate of 0.35 cm per day.

According to the results presented in the Table 4, 60 days after sowing and 2 compost applications parsley grew by 15 cm, indicating a growth rate of 0.25 cm per day, whilst 67 days after sowing and 2 compost applications parsley grew by 17 cm, indicating a growth rate of 0.25 cm per day. Likewise, 74 days after sowing and 2 compost applications parsley grew by 30 cm, indicating a growth rate of 0.41 cm per day. It is recommended to harvest the parsley in 74 days to produce appropriate height plant, almost 30 cm height for commercial product of parsley. It is also observed that in a week it had a rapid increase regarding its height. Worth noting is the fact that 54 days after the 1st harvest parsley height reached 21 cm, nominating a satisfactory growth rate of 0.35 cm per day.

According to the results presented in the Table 5, 72 days after sowing and 2 compost applications celery grew by 12 cm, indicating a growth rate of 0.17 cm per day, while 80 days after sowing and 2 compost applications celery grew by 18 cm, indicating a growth rate of 0.23 cm per day. Likewise, 106 days after sowing and 2 compost applications celery grew by 27 cm, indicating a growth rate of 0.25 cm per day. It is recommended to harvest the celery in 106-160 days to produce appropriate height plant, which is around 18 cm height for commercial product of celery.

According to the results presented in the Table 6, 54 days after sowing and 2 compost applications dill grew by 14 cm, indicating a growth rate of 0.26 cm per day, whilst 61 days after sowing and 2 compost applications dill grew by 17 cm, indicating a growth rate of 0.28 cm per day. Similarly, 68 days after sowing and 2 compost applications dill grew by 26 cm, indicating a growth rate of 0.38 cm per day. It is recommended to harvest the dill in 71-100 days to produce appropriate height plant, which is around 25 cm height for commercial product of dill.

Further, foliar analysis of *Eruca sativa*, *Eruca vesicaria*, parsley, celery and dill leaves took place and the results have been compared to their mean values according to U.S. Department of Agriculture [24] and are presented in Table 7.

Table 3: Growth monitoring of *Eruca vesicaria*.

Eruca vesicaria	**Date**	**Height (cm)**
sowing	15 October 2020	
stem	25 October 2020	
1st application of compost	1 December 2020	11
	7 December 2020	14
2nd application of compost	14 December 2020	15
	21 December 2020	20
1st harvest	21 December 2020	20
2nd harvest	22 February 2021	21

Table 4: Growth monitoring of parsley.

Parsley	**Date**	**Height (cm)**
sowing	15 October 2020	
stem	30 October 2020	
1st application of compost	1 December 2020	11
	7 December 2020	13
2nd application of compost	14 December2020	15
	21 December 2020	17
1st harvest	28 December 2020	30
2nd harvest	22 February 2021	27

Table 5: Growth monitoring of celery.

Celery	**Date**	**Height (cm)**
sowing	20 October 2020	
stem	20 November 2020	
1st application of compost	1 December 2020	2.5
	7 December 2020	5
2nd application of compost	14 December 2020	8
	21 December 2020	9
	31 December 2020	12
	8 January 2021	18
harvest	4 February 2021	27

Table 6: Growth monitoring of dill.

Dill	**Date**	**Height (cm)**
sowing	20 October 2020	
stem	30 November 2020	
1st application of compost	1 December 2020	10
	7 December 2020	12
2nd application of compost	14 December 2020	14
	21 December 2020	17
harvest	28 December 2020	26

Table 7: Chemical parameters of foliar analysis of crops compared to their mean values according to USDA (U.S. Department of Agriculture) [24].

	Eruca sativa	*Eruca vesicaria*	USDA mean value	Parsley	USDA mean value	Celery	USDA mean value	Dill	USDA mean value
P (%)	0.3	0.3	0.63	0.3	0.47	0.2	0.51	0.24	0.47
K (%)	3.4	3.8	4.34	3.9	4.5	3.8	3.89	3.53	5.27
Ca (%)	2.2	2.4	1.93	1.2	1.12	0.8	0.27	0.97	1.49
Mg (%)	0.5	0.4	0.57	0.3	0.41	0.3	0.21	0.57	3.93
Fe (mg/kg)	91.3	140	176	71.2	504	99.9	44.4	116.5	471
Mn (mg/kg)	28.8	39.4	38.7	32	13	33.2	15.4	38.5	90
Zn (mg/kg)	34.7	37.1	56.6	21.9	87	14.3	3.33	38.5	65
Cu (mg/kg)	4.85	6.20	9.16	7.60	12.1	2.60	14.3	5.86	10.4
B (mg/kg)	19.0	24.6		28.4		23.9		29.0	
$N_{Kjeldahl}$ (g/kg)	23.7	21.1		18.6		16.8		19.7	15.1

Regarding phosphorus, there were clearly reduced values for all five vegetables in relation to their USDA mean values, while potassium concentrations show slightly lower values. Calcium and magnesium levels were quite similar to those of USDA, with the exception of dill magnesium content which is quite reduced. As far as iron content, great differentiation was observed in parsley and dill, in which the values were obviously higher. Concerning manganese, concentrations of all five crops were similar to those of USDA, whilst zinc and copper content was satisfactory in terms of *Eruca sativa, Eruca vesicaria*, parsley and dill. As regards boron and nitrogen concentrations, their concentrations ranged within the permissible value ranges [25].

Conclusions

This study was an initial assessment of vermicomposted cow manure as potential soil amendment for the production of organic early crops vegetables in the greenhouse of Green Unit of the Psychiatric Hospital of Thessaloniki. Soil analysis after the vermicompost application showed marked improvements in the chemical properties of the soil, while it did not affect physical and microbiological properties of the greenhouse soil. These properties were related to growth responses and production period of organic early crops vegetables (*Eruca sativa, Eruca vesicaria* , parsley, celery and dill), and results showed that the use of vermicomposted cow manure has quite satisfactory results in their production, in the context of sustainable development and circular economy, as cow manure is exploited as an organic fertilizer and so, environmental degradation expected from land disposal of untreated cow manure is minimized. Furthermore, with the proposed organic fertilizer application plan it was calculated how long after sowing the producer can market the above crops, while at the same time an attempt was made to compare the nutrient content of the produced crops in the greenhouse in relation to their mean value according to USDA. More research is needed to study the differences that emerged from this comparison, as well as to improve the method.

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