Tikrit Journal for Agricultural Sciences
ISSN:1813-1646 (Print); 2664-0597 (Online)
Journal Homepage: http://www.tjas.org
E-mail: tjas@tu.edu.iq

TJAS
Tikrit Journal for Agricultural Sciences

DOI: https://doi.org/10.25130/tjas.25.2.17

Effect of vermicompost tea addition methods on growth and yield of lettuce (*Lactuca sativa*)

Kutaiba Y. Aied [1], Mohammed J. Farhan [2] and Ghassan J. Z. [1]
1 Department of Horticulture and Landscape, College of Agriculture, Tikrit University, Tikrit, Iraq.
2 Department of Soil Science and Water Resource, College of Agriculture, Tikrit University, Tikrit, Iraq.

Corresponding email: qu_802000@tu.edu.iq

KEY WORDS:
Lettuce, vermicompost, compost tea, oil, organic matter

Received: 09/08/2024
Revision: 20/12/2025
Proofreading: 12/01/2025
Accepted: 17/01/2025
Available online: 30/06/2025

ABSTRACT
Low soil fertility results in lower productivity. Constantly exposed to chemical fertilizers leads to the health risks. The focus recently faces to organic productivity. Vermicompost is one of an important organic fertilizer, its beneficial for sustainable production. Therefore, this study was conducted at research station in Department of Horticulture and Landscape/ College of Agriculture/ Tikrit University to evaluate the addition of vermicompost with high advantages in the growth and yield of lettuce in different methods viz, control (C), add regular soil mixed with soil (V1), add compost tea in one batch (V2), add compost tea in two batches (V3), dilute compost tea to 50% concentration and add twice (V4) and dilute compost tea to 25% concentration and add weekly in four batches (V5). The experiment was laid out according to Randomized Complete Block Design (RCBD) The comparison of means was performed by Least Significant Difference at a P≤ 0.05 probability level. Results showed that V4 gave significant increment in chlorophyll, percentage dry matter, nitrogen, phosphorous and potassium in leaves, additionally organic matter nitrogen, phosphorous and potassium in soil. On the other hand, V1 had highest values in root weight, length of largest leaf and stem diameter. Meanwhile, V5 treatment increased significantly in total number of leaves, Width of largest leaf and percentage of oil in leaves. This indicates the importance of adding vermicompost, either directly or as compost tea at a concentration of 50% in two batches, in improving soil properties and lettuce growth and yield characteristics.

تاثير طرق إضافة شاي الفيرمي كومبوست في نمو وحاصل الخس *Lactuca sativa*

قتيبة عايد[1] و محمود فرحان[1] وغسان جايد[2]

[1]قسم البستنة وهندسة الحدائق – كلية الزراعة – جامعة تكريت –العراق

[2]قسم التربة والموارد المائية - كلية الزراعة – جامعة تكريت –العراق

الخلاصة

يؤدي انخفاض خصوبة التربة إلى انخفاض الإنتاجية، وان الاستخدام المستمر للأسمدة الكيماوية يؤدي إلى مخاطر صحية. لذلك يتجه التركيز مؤخرًا إلى الإنتاج العضوي، ويعد السماد الدودي (Vermicompost) أحد الأسمدة العضوية المهمة للإنتاج المستدام. لذلك، أجريت هذه الدراسة في محطة الأبحاث في قسم البستنة وهندسة الحدائق / كلية الزراعة / جامعة تكريت لتقييم إضافة السماد الدودي ذات المزايا العالية في نمو وإنتاجية الخس بطرق مختلفة وهي المقارنة (C) إضافة تقليدية للسماد الدودي مزجا مع التربة (V1) إضافة شاي السماد الدودي في دفعة واحدة (V2) وإضافة شاي السماد في دفعتين (V3) وتخفيف شاي السماد إلى تركيز 50٪ وإضافته مرتين (V4) وتخفيف شاي السماد إلى تركيز 25٪ وإضافته أسبوعيًا في أربع دفعات (V5). تم تنفيذ التجربة وفقًا لتصميم القطاعات الكاملة العشوائية (RCBD) وتم مقارنة المتوسطات باستخدام أقل فرق معنويLSD عند مستوى احتمال $P \leq 0.05$. أظهرت النتائج أن المعاملة V4 أعطت زيادة معنوية في الكلوروفيل ونسبة المادة الجافة والنيتروجين والفوسفور والبوتاسيوم في الأوراق بالإضافة إلى المادة العضوية والنيتروجين والفوسفور والبوتاسيوم في التربة. من ناحية أخرى، سجلت المعاملة V1 أعلى القيم في وزن الجذر وطول أكبر ورقة وقطر الساق. في حين زادت معاملة V5 بشكل ملحوظ في العدد الكلي للأوراق وعرض أكبر ورقة ونسبة الزيت في الأوراق. وهذا يدل على أهمية إضافة الفيرمي كومبوست سواء بشكل مباشر او كشاي الكومبوست بتركيز 50% على دفعتين في تحسين صفات التربة وصفات نمو وحاصل الخس.

الكلمات الافتتاحية : الخس، السماد الدودي، شاي السماد، الزيت، المادة العضوية

INTROUCTION

Lettuce (*Lactuca sativa* L.) is an important vegetable plant belonging to the salad family or the Compositae family, sometimes called the Asteraceae family, and it is the most popular salad crop in the world. Its origin is Europe, Asia and North Africa. Lettuce is one of the most consumed vegetables in the world because it is a good source of fiber and low in calories, fat and sodium. In addition, it is a good source of iron, folic acid and vitamin C, and is very good for health from various biologically active compounds (Kim *et al*., 2016). It is an annual herbaceous plant that grows vertically from (12.5 to 25) cm in leaves, and height plant reaches to 50 cm (Ali *et al*., 2016). Soil and its condition are important for agricultural production, with degraded soil and low productivity being major constraints to food security (Natsheh and Abu-Khalaf, 2015). Due to the negative impacts of chemical fertilization on the environment. Organic fertilizers may be a better option, with numerous benefits for the plant, soil and environment (Leogrande *et al*., 2013). Organic fertilizers are very important for improving soil properties as they not only contain the required nutrients but also have positive effects on the overall soil productivity and can be used effectively in conventional agriculture as a primary method for improving soil fertility (Bharambe, 2015).

Vegetable farming is an important agricultural activity in the world, and farmers are always looking for effective ways to increase crop yields and improve their growth. One common way to

improve soil quality is to use compost, which contains decomposed organic matter that improves soil structure and provides nutrients needed for plant growth. One of the amazing benefits of compost is compost tea, which is extracted from it after fermentation and used as a liquid for irrigation. Eudoxie *et al*. (2019) indicated the presence of nutrients, plant hormones and some other biologically active compounds in compost tea. Four concentrations of aerated compost tea (0, 5, 10 and 20%) were used per 100 or 200 cm3 plant-1 daily for 30 days on lettuce grown under a greenhouse. The yield increased significantly with increasing the concentration to 10% compared to the control treatment, but the yield decreased with increasing the concentration to 20%. A close correlation was observed between the concentration of added fertilizer and the concentration of nitrogen in the leaves and roots of lettuce.

The use of compost tea has become interesting in organic farming applications, which are oxygenated extracts of compost that give positive effects on crops because they contain biologically active molecules and microorganisms that improve plant growth. Studies have shown that using compost from plant residues improves the growth and production of some vegetable crops, such as potatoes and kohlrabi (Ghassan *et al*., 2024; Al-Azzawi and Ghassan, 2024). Also, a study was conducted to evaluate the effect of compost tea as foliar spray and irrigation, on the cultivation of lettuce and kohlrabi. The extract was extracted from compost of artichoke and fennel plant residues. The treatment resulted in a significant improvement in crop yield. The commercial lettuce production increased by 24%. Due to the improved physiological and nutritional status of the plants, encouraging indicators of leaf chlorophyll content were also observed (Pane *et al*., 2014).

Plant extracts are novel, natural, multi-component products that can be used for a variety of purposes including stimulants, fertilizers, and biocides. They have antifungal, antimicrobial, antiparasitic, antioxidant, medicinal, aromatic, and anti-inflammatory properties. This group of natural products has the potential to become a new generation of bioproducts suitable for use in sustainable agriculture. The application of these bioproducts can be beneficial for sustainable production, due to several advantages, such as low toxicity to humans and the environment, enhanced resistance of cultivated plants to biotic and abiotic stress, increased yield and crop quality, as well as reduced use of mineral fertilizers and pesticides (Godlewska *et al*., 2021).

Therefore, the aim of this study is to improve the growth and yield of lettuce by finding the best way to add organic vermicompost, especially with the development of irrigation techniques and the possibility of adding organic fertilizers easily through irrigation systems when converted into organic extracts such as compost tea.

MATERIAL AND METHODS

Location of the Experiment and its Layout

The experiment was conducted at an experiments station at the Department of Horticulture and Landscape/ College of Agriculture/ Tikrit University in Tikrit, Iraq. The experimental station area is situated at 34o 40/ 51.93// N latitude and 43o 38/ 59.87// E longitude. Sand clay loam soil was used. A soil sample was gathered from 0-15 cm depth. This sample helped determine the chemical and physical characteristics before soil was fertilized. The chemical properties of the gathered sample were ascertained using this technique (Hunter, 1984). The soil was mildly alkaline (pH 7.6) with inadequate fertility; the organic material was 1.13 g kg-1. Element availability was at 48 mg kg-1 N, 6.8 mg kg-1 phosphorous, and 195 mg kg-1 potassium. Moreover, other

properties include 1.4 g cm-3 bulk density, 2.23 ds m-1 EC, 15 cmol kg-1 soil CEC, 158 mg kg-1 CaCo3 and 130 mg kg-1 CaSo4.

The test evaluated the Fajir hybrid lettuce (Lactuca sativa L.) (Netherland origin), It is one of the new hybrids that have been popularly cultivated in Iraq recently. It is characterized by its medium-sized head and its tolerance to high temperatures. before planting, soil preparation was done to build about 20 cm height ridges. The drip irrigation approach was used, then covered the ridging by black mulching for weed control. The seedlings were hand planted on 27th October 2022. The ridges were separated by 1 m, while a 30 cm separation among plants was maintained within a ridge; Pests and other harmful organisms were kept in check based on conventional cultivation standards.

Preparing of Tea Compost

Tea compost was made by adding 1 liter of water to 150 grams of vermicompost with a moisture content of 50% and leaving it for two weeks with continuous daily stirring (Al-Saffah and Aied, 2021). Then it was filtered and added directly according to the above treatments. Table 1 lists an assessment of tea compost, according to manufacturing company.

Table 1. Chemical and physical properties of vermicompost

Vermicompost	mg kg^{-1}							
	Fe		Zn		Mn		Cu	
	36-50		27-40		15-25		5-90	
Moisture (%)	EC (dsm)	pH	OM (%)	OC (%)	N (%)	C/N	P_2O_5 (%)	K_2O (%)
25	1.1	7.66	32.77	20	1.69	15-25	0.0103	0.394

Treatments

The plot was 0.75 m wide and 1 m long (0.75 m2); there were 1 m wide corridors between the plots. Every fertilization test comprised 3 identical samples; hence, 18 plots were tested for the study. The study comprised 6 fertilizer treatments: (i) Control (C0) without compost use, (ii) add traditional mixed with soil (150 g per experimental unit) two weeks after planting (V1), add tea compost once after two weeks of planting (V2), add tea compost twice (two weeks after planting and one week after the first addition) (V3), 50% of tea compost was added twice (two weeks after planting and one week after the first addition) (V4), and 25% of tea compost was added weekly in four times starting from the second week of planting (V5).

Data Recorded

The lettuce plants were harvested 78 days after transplanting. Random selection was used to identify five plants from every plot. The plants were uprooted to measure plant height, chlorophyll in leaves, root weight, total numbers of leaves, numbers of outer leaves, length and width of largest leaf, stem diameter, length of internal stem, head circumference, head weight, marketable head weight, percentage of marketable yield, percentage of dry matter, percentage of nitrogen, phosphorous, potassium and oil in leaves. Additionally organic matter, percentage of nitrogen, phosphorus and potassium in soil.

Statistical Analysis

The experiment was designed in one way Randomized Complete Block Design (RCBD) and replicated three times. The analysis of variance was carried out using SAS program (version 9). Mean values were separated based on Least Significant Difference Test (LSD) at 0.05 probability levels.

RESULTS AND DISSCUSION

The traits of vegetative growth due to the treatments varied. The V4 treatment showed remarkable increase in chlorophyll gave highest value41.60 SPAD but not significant with V1, V2 and V5 treatments, while control treatment gave lowest value 37.99 SPAD. On other hand, control treatment gave less value in root weight 118.17 g compared to other treatment (Table 2).

Table 2. Effect of vermicomposting tea addition on traits of vegetative growth.

Traits / Treatments	Plant height (cm)	Chlorophyll (SPAD)	Root weight (g)	Total number of leaves (leaf plant-1)	No. of outer leaves (leaf plant-1)	Length of largest leaf (cm)	Width of largest leaf (cm)	Stem diameter (cm)	Length of internal stem (cm)
C0	36.00	37.99	118.17	62.50	23.67	32.17	17.50	30.07	22.50
V1	39.67	39.72	160.83	66.00	25.83	35.33	18.67	32.79	19.83
V2	39.83	39.78	148.33	67.83	29.00	32.67	18.17	30.89	27.83
V3	37.50	39.06	157.50	65.67	28.00	33.17	18.83	27.67	20.50
V4	37.67	41.60	151.67	64.33	23.50	31.17	17.00	31.17	19.83
V5	38.67	40.26	153.33	68.17	24.56	33.83	19.22	31.78	21.83
LSD	3.76	2.11	22.29	4.33	9.60	3.18	1.85	1.80	5.44
CV	12.82	17.52	5.62	18.04	5.56	13.17	11.77	10.89	4.23

C0= Control, V1= Add traditional mixed with soil (150 g per experimental unit) two weeks after planting, V2= Add tea compost once after two weeks of planting, V3= Add tea compost twice (two weeks after planting and one week after the first addition), V4= 50% of tea compost was added twice (two weeks after planting and one week after the first addition), V5= 25% of tea compost was added weekly in four times starting from the second week of planting. LSD=Least significant difference. CV= Coefficient of variation.

Maximum and significantly higher total number of leaves and width of largest leaf 68.17 leaf plant-1 and 19.22 cm respectively, in V5 treatment. Meanwhile, V1 treatment gave highest values in length of largest leaf and stem diameter 35.33 cm and 32.79 ml respectively. On the other hand, V2 treatment had highest value in length of internal stem 27.83 cm. At the same time, there were no significant difference among different treatments for other studied traits. Data presented in Table 3 showed that the varied treatments didn't affect significantly on Head circumference, head weight, marketable head and percentage of marketable yield. With respect to the percentage of dry matter, nitrogen, phosphorous and potassium of the leaves, the results from the contrast analysis showed that the V4 treatment performed better than those that received the control treatment. Also, a large variation was seen in the values due to the multiple treatments being visited upon the soil. The V5 treatment greatly increased the level of oil in the leaves 2.69% compared with control treatment 2.28%. In general, the positive effect of adding vermicompost was clearly observed in improving the growth and yield characteristics of lettuce, although the differences in the head weight characteristics were not significant. These results agree with what was found by Frasetya et al. (2019), Kiran (2019) and Adiloğlu et al. (2018) who found a significant increase in

the height, number of leaves, fresh weight of leaves, chlorophyll content, plant size, length and width of leaf per plant and dry matter productivity of lettuce at addition of vermicompost.

Table 3. Effect of vermicompost tea addition on yield traits

Traits / Treatments	Plant height (cm)	Chlorophyll (SPAD)	Root weight (g)	Total number of leaves (leaf plant-1)	No. of outer leaves (leaf plant-1)	Length of largest leaf (cm)	Width of largest leaf (cm)	Stem diameter (cm)	Length of internal stem (cm)
C0	46.83	1223.50	720.83	52.06	10.42	2.80	0.27	1.67	2.28
V1	51.50	1515.00	827.50	55.78	9.26	3.02	0.35	2.04	2.50
V2	49.50	1590.00	850.83	53.54	9.60	2.82	0.29	1.94	2.43
V3	49.33	1387.50	685.83	49.50	9.63	2.91	0.34	2.04	2.68
V4	46.50	1323.33	683.33	55.53	10.83	3.52	0.48	2.20	2.58
V5	50.44	1427.50	747.77	52.55	9.90	2.93	0.31	1.96	2.69
LSD	8.72	459.90	236.80	6.86	0.67	0.43	0.096	0.20	0.29
CV	8.36	4.73	4.80	11.09	12.21	6.48	3.22	9.25	8.65

C0= Control, V1= Add traditional mixed with soil (150 g per experimental unit) two weeks after planting, V2= Add tea compost once after two weeks of planting, V3= Add tea compost twice (two weeks after planting and one week after the first addition), V4= 50% of tea compost was added twice (two weeks after planting and one week after the first addition), V5= 25% of tea compost was added weekly in four times starting from the second week of planting. LSD=Least significant difference. CV= Coefficient of variation.

The positive effect of vermicompost on improving traits of growth, yield and nutrient concentrations in lettuce crop is due to the vermicompost contains nutrients and organic matter that improve soil properties (Table 1), as humus compounds improve the physical, chemical and biological properties of the soil, increasing root zone aeration and water retention capacity, rehabilitating soil structure, providing plant nutrients and forming natural media for microorganisms with their regulatory effects on soil interactions (Durak, 2017). This is what Demir (2019) found in the good effect of vermicompost on improving the physical properties of the soil and lettuce yield, as he found that the highest lettuce yield was when adding vermicompost compared to other treatments.

The result indicates that vermicompost tea application especially with V4 treatment significantly increased soil organic matter, nitrogen, phosphorus and potassium 160.99, 181.50, 671.26 and 35.66% respectively compared to control treatment which significantly reduced in these traits 9.46 g kg soil-1, 14.49 ppm, 3.48 ppm, and 183.08 ppm respectively (Table 4).

This increase in the amount of organic matter in the soil in treatment V4 may be attributed to the increase in the biomass in the soil that comes from the added fertilizer as well as the activity of the enzymes added from the fertilizer, including the phosphatase enzyme (Ali et al., 2015). Also, the significant increase in the availability of nutrients nitrogen, phosphorus and potassium as a result of adding vermicompost may be due to the good features of this fertilizer, including the high CEC value, which is one of the most important characteristics of soil element availability, as well as the fertilizer containing humic acids, which play an important role in reducing the degree of pH and thus increasing the availability of nutrients in the soil (Sinha et al., 2009). In addition, this fertilizer contains many nutrients, including NPK, as a result of its original plant or animal source, which is released into the soil through the mineralization process carried out by soil organisms. Therefore, this fertilizer will play an important role by preserving the elements in the soil from loss and increasing their availability for the plant (Hazar, 2016).

Table 4. Effect of vermicompost tea addition on some chemical traits of soil

Traits Treatments	Organic matter (g kg soil-1)	Nitrogen (ppm)	Phosphorous (ppm)	Potassium (ppm)
C0	9.46	14.49	3.48	183.08
V1	19.65	24.91	11.87	210.60
V2	16.65	20.90	8.65	197.47
V3	21.83	33.56	20.00	212.06
V4	24.69	40.79	26.84	248.37
V5	22.89	37.63	21.60	239.13
LSD	1.89	1.74	1.77	11.95
CV	3.46	2.95	1.84	8.95

C0= Control, V1= Add traditional mixed with soil (150 g per experimental unit) two weeks after planting, V2= Add tea compost once after two weeks of planting, V3= Add tea compost twice (two weeks after planting and one week after the first addition), V4= 50% of tea compost was added twice (two weeks after planting and one week after the first addition), V5= 25% of tea compost was added weekly in four times starting from the second week of planting. LSD=Least significant difference. CV= Coefficient of variation.

CONCLUSION

The results indicate the clear role of vermicompost, through its various addition methods, in improving soil properties and the availability of elements in it, which was positively reflected in improving plant growth and yield.

REFRANCES

Adiloğlu, S., Açıkgöz, F. E., Solmaz, Y., Çaktü, E., & Adiloğlu, A. (2018). Effect of vermicompost on the growth and yield of lettuce plant (*Lactuca sativa* L. var. crispa). *International Journal of Plant & Soil Science*, *21*(1), 1-5.

Al- Azzawi, H. A. and Ghassan, J. Z. (2024). Role of sowing date and fertilizers of mineral and organic on qualitative of kohlrabi (*Brassica oleracea* var. gongylodes). *Tikrit Journal for Agricultural Sciences*, 24(4): 158-166.

Ali, U., Sajid, N., Khalid, A., Riaz, L., Rabbani, M. M., Syed, J. H., & Malik, R. N. (2015). A review on vermicomposting of organic wastes. *Environmental Progress & Sustainable Energy*, *34*(4), 1050-1062.

Ali, W., Hamiduddin, Ahmad. A., Aslam, M., Nasir, A. (2016) Tukh-E-Kahu (Lactuca sativa LINN): Pharmacological and Phytochemical Profile and Uses is Unani Medicine. *J. Pharm. Sci. Innov.*, 5(1):1-4.

Al-Saffah, F. M. and Aied, K. Y. (2021). The effect of using vermicompost fertilizer and vertical cultivation on the yield of two varaieties of tomato *Solanum lycopersicon* Mill. *Plant Cell Biotechnology and Molecular Biology,* 22(21@22):127-138.

Bharambe C. M. (2015). Comparative Assesment of Bat Guano as an Excelent Bio Compost in Reference to NPK. 2(2): 20-21.

Demir, Z. (2019). Effects of vermicompost on soil physicochemical properties and lettuce (*Lactuca sativa* Var. Crispa) yield in greenhouse under different soil water regimes. *Communications in Soil Science and Plant Analysis*, *50*(17), 2151-2168.

Durak, A., Altuntaş, Ö., Kutsal, İ. K., Işık, R., & Karaat, F. E. (2017). The effects of vermicompost on yield and some growth parameters of lettuce. *Turkish Journal of Agriculture-Food Science and Technology*, *5*(12), 1566-1570.

Eudoxie , G., Grogan, K., Beckford, M. and Martin, M. (2019). Compost tea influence on lettuce (*Lactuca sativa* L.) root architecture. Acta Hortic. 1266, 79-88. DOI: 10.17660/ActaHortic.2019.1266.12 .https://doi.org/10.17660/ActaHortic.2019.1266.12

Frasetya, B., Harisman, K., Maulid, S., & Ginandjar, S. (2019, December). The effect of vermicompost application on the growth of lettuce plant (*Lactuca sativa* L.). In *Journal of Physics: Conference Series* (Vol. 1402, No. 3, p. 033050). IOP Publishing.

Ghassan, J. Z., Aied, K. Y. and Alkurtany, A. E. S. (2024). Assessing the compost of *Prosopis farcta* and *Alhagi maurorum* as organic fertilizer for potato growth and yield (*Solanum tuberosum* L.). *Tikrit Journal for Agricultural Sciences*, 24(2): 178-196.

Godlewska , K. ., Ronga, D. ., & Michalak, I. (2021). Plant extracts - importance in sustainable agriculture. *Italian Journal of Agronomy, 16(2).* https://doi.org/10.4081/ija.2021.1851

Hazra, G. (2016). Different types of eco-friendly fertilizers: An overview. *Sustainability in Environment*, 1(1), 54-70.

Hunter, A. H. (1984). *Soil fertility analytical service in Bangladesh: a consultancy report of 1984*, Bangladesh Agricultural Research Council, Dhaka, Bangladesh, 49.

Kim, M., Moon, Y., Tou, J.C., Mou, B., Waterland, N. (2016). Nutritional value, bioactive Compounds and health benefits of lettuce (*Lactuca sativa* L.). *Journal of Food Composition and Analysis*, 49: 19-34.

Kiran, S. (2019). Effects of vermicompost on some morphological, physiological and biochemical parameters of lettuce (*Lactuca sativa* var. crispa) under drought stress. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *47*(2), 352-358.

Leogrande, R., Lopedota, O., Fiore, A., Vitti, C., Ventrella, D., Montemurro, F. (2013). Previous crops and organic fertilizers in lettuce: Effects on yield and soil properties. *Journal of Plant Nutrition*, 36: 1945-1962.

Natsheh, B. and Abu-Khalaf, N. (2020). Influence of Different Types of Fertilizers Application on the Lettuce (*Lactuca Sativa* L.) Growth and Quality**.** *Palestine Technical University Research Journal*, 8(2).

Pane, C., Palese, A. M., Celano, G., & Zaccardelli, M. (2014). Effects of compost tea treatments on productivity of lettuce and kohlrabi systems under organic cropping management. *Italian Journal of Agronomy*, 9(3), 153–156. https://doi.org/10.4081/ija.2014.596.

Sinha, R. K., Herat, S., Valani, D., & Chauhan, K. (2009). Special Issue: Vermiculture and sustainable agriculture. *American-Eurasian Journal of Agricultural and Environmental Science*, *5*.