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VERMICOMPOST PRODUCTION AND ITS IMPORTANCE FOR SOIL AND AGRICULTURAL PRODUCTION

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Abstract

The vermicompost (earthworm humus) is a particularly effective fertilizer for both vegetables and fruits, as well as for large crops. This fertilizer has, in a high percentage all of the 16 nutrients that are essential for plants. The vermicompost is obtained through the aid of Eisenia fetida (Savigny), also known as: "compost earthworm", "red earthworm", "redworm" "brandling worm". Eisenia fetida is a species of earthworm developed by researchers and geneticists in the 1950's and 1960's, having a much higher reproductive capacity and better adaptability to the living environment than other existing species. It was first used in the USA in farms where large quantities of biomass and natural fertilizers were needed. In addition, this species of earthworm processes large amounts of biodegradable organic waste more rapidly with maximum productivity of natural humus. Thanks to these benefits, farmers around the world began to grow earthworms and produce vermicompost in a growing number. One of the most important advantages of using the vermicompost is that it increases production, both in terms of quantity and quality.
Another advantage is that it helps in the suppression of harmful fungi in the soil. These microorganisms produce hormones, vitamins, nutrients, enzymes, amino acids and minerals that are important for plants.
The vermicompost has a positive effect not only on plants but also on the soil. It greatly improves the structure of the soil, decreasing its density, increasing the aeration and the absorption of nitrogen from the atmosphere. Therefore, it repairs the soils affected by the long-term use of chemical substances.

Key words: *eartworms, vermicompost, nutrients, soil fertility.*

INTRODUCTION

"Nobody and nothing can be compared with earthworms and their positive influence on the whole living Nature. They create soil and everything that lives in it. They are the most numerous animals on Earth and the main creatures converting all organic matter into soil humus providing soil's fertility and biosphere's functions: disinfecting, neutralizing, protective and productive" (Igonin, 2004).
Aristotle called the earthworms "intestines of the earth" and Charles Darwin wrote a book about earthworms and their activities, saying that there may not be another creature that played such an important role in the history of life on Earth (Bogdanov, 1996).
Vermiculture is the culture of earthworms. Its goal is to continuously increase the number of earthworms in order to achieve a sustainable population. The earthworms are either used to expand a vermicompost operation or are sold to customers who use them for the same or for other purposes (Munroe, 2007).
Vermicomposting is the process where earthworms are used to convert organic materials (usually waste) into humus-like material known as vermicompost (Munroe, 2007).

MATERIALS AND METHODS

It is estimated that there are over 1800 species of earthworms worldwide (Edwards & Lofty, 1972), but only one species, *Eisenia fetida* (Savigny), also known as: "*compost earthworm*", "*red earthworm*", "*redworm*" "*brandling worm*" is being discussed in this paper.
Eisenia fetida is a species of earthworms developed by researchers and geneticists in the 1950's and 1960's, with a much higher reproductive capacity and a better adaptability to the living environment than the existing species. It was first used in the USA on farms where large amounts of biomass and natural fertilizers were needed. In addition, this earthworm species processes much more

rapidly large amounts of biodegradable organic waste with a maximum productivity of natural humus. Due to these benefits, farmers around the world began to grow earthworms and to produce vermicompost in a growing trend.

In the present, the largest vermicompost production centers are in India and Cuba, countries that are currently leaders in this field. In India, it is estimated that around 200,000 farmers practice vermicomposting and a network of 10,000 farmers produces 50,000 metric tons of vermicompost each month. Over the last decade, farmers in Australia and the USA'a West Coast began to use vermicompost in large quantities, fueling the development of the vermicompost industry in these regions. At the same time, scientists from several universities in the USA, Canada, India, Australia and South Africa began to document the benefits associated with the use of the vermicompost, providing facts and figures to support the observations of those who actively used the material (Munroe, 2007).

Composting earthworms live in "nests" estimated at 100,000 individuals (Figure 1).

Figure 1. Soil composting with earthworms

They are hermaphrodites, and they double their number in a cycle of around 100 days. The nest has a surface of 2 m^2 and a thickness of 25 cm. For a nest it is necessary to have an area of 2 m^2, in the shape of an alley, on which the bedding is formed.

Preparing the bedding

One of the main activities in raising earthworms is bedding preparation. The substrate of the bedding is a layer of organic materials rich in cellulose, where the earthworms build their habitat from where they will go to the top to feed themselves (Duşan, 2013). Over this substrate there is the food (manure) layer, which should not be disturbed during the earhworms' habitation (Figure 2).

Figure 2. Preparing the bedding

The bedding's substrate must meet two basic requirements:

a. To have the property of maintaining moisture (the earthworms require a high degree of moisture in the environment in which they live and multiply because they breathe through their skin and take oxygen out from the water;
b. It must be porous, aggregated soil represents the amorphous surface in the bedding and it prevents the penetration of oxygen into the substrate (Duşan, 2013).

If available, shredded paper or paperboard are an excellent bedding material (Georg, 2004), especially when combined with typical organic farm resources, such as straws and hay.

Optimum oxygen quantities facilitate the decomposition of garbage into nutrients. A well-fed earthworm in a well-protected substrate lives peacefully and multiplies intensely producing cocoons with more hatchlings in them (a cocoon contains 10-12 hatchlings) (Duşan, 2013).

It is very important that the substrate, in addition to being aerated, it should also allow the formation of bacteria, which make the primary food preparation, without which, regardless of the quantity or quality of food, the earthworms die (Duşan, 2013).

The natural habitat for earthworms is, in general, as known, given by the deposits of manure and vegetal residues. All the research and experience gained so far shows that the more the artificial habitat resembles the natural one, the more the success in growing earthworms will be greater. The best earthworm food and the best biohumus are obtained if manure is given (Table 1) from horses, cows, sheep, rabbits, goats, provided that it is pre-composted and that it passed the fermentation phase.

Table 1. Common Worm Feed Stocks (Munroe, 2007)

Food	Advantages	Disadvantages	Comments/Notes
Cattle manure	Good nutrition, natural food, therefore it requires little adaptation	Weed seeds make pre-composting necessary.	The manure is partially decomposed and therefore ready for consumption by the earthworms.
Poultry manure	High nitrogen content, has as result a good nutrition and a high-value product	High levels of protein can be dangerous for earthworms, so they should be used in small quantities; there is a need for a major adaptation process for the earthworms that are not used to this raw material. It can be pre-composted but it's not a must, if used with caution.	Gaddie and Douglas (1975) suggest that poultry waste is not suitable for earthworms, because it is too "hot"; however, researchers from Nova Scotia (Georg, 2004) have shown that earthworms can adapt if the original proportion of poultry manure in the bedding is 10% of the total volume or less.
Sheep/Goat manure	Good nutrition	Requires pre-composting (due to weed seeds); small-sized particles can lead to agglomeration, therefore it requires additional bulking materials.	With the right additives to increase the Carbon/ Nitrogen ratio, this fertilizer is also good as a bedding.
Pig manure	Good Nutrition; produces an excellent vermicompost	It is ually in liquid form, it should therefore be dehydrated or used with large amounts of highly absorbent bedding.	Scientists from Ohio State University have discovered that vermicompost made from pig manure has outperformed all other vermicomposts and commercial fertilizers as well.
Rabbit manure	The nitrogen content is similar to that of poultry manure, so it provides good nutrition; it contains a very good mixture of vitamins and minerals and can be an ideal food for earthworms (Gaddie and Douglas, 1975)	It must be leached before use due to the high urine content; it can overheat if the quantities are too high, it's also not usually available.	Many rabbit breeders in the USA place the earthworms under the rabbit cages in order to catch the pellets as they fall through the wire mesh cage floors.

In the earthworm's diet there can also be used: fresh food scraps (egg shells, other waste from food preparation, food waste from commercial food processing), pre-composted food waste, biosolids (human waste), seaweed, legume hays, grains (feed mixtures for animals, such as poultry feed concentrates), corrugated cardboard (including waxed cardboards), fish, poultry meat residues, blood waste, dead animals. If the resulting vermicompost is used in organic farming, some of the residues listed above can not be used in earthworm diet.

Earthworm care

Earthworms usually do not get ill (they are not attacked by viruses and bacteria), so the only enemy that can cause them harm can only prove to be man through its negligence. Their care requires little work at fairly long intervals, therefore, in case of forgetfulness or other reasons, they can remain unfed (food is given every 15 days), or even dehydrated below the optimal humidity level.

Humidity

In regards to moisture, the range within which the ideal moisture content can be found for materials in conventional composting systems is between 45-60% (Rink et al., 1992), but in contrast to the conventional practice, the ideal humidity range for vermicomposting or the vermiculture process is of 70-90%. In this wide range, researchers found slightly different optimal values: Dominguez & Edwards (1997) found that the best range would be of 80-90%, with 85% being optimal, while researchers in Nova Scotia found out that 75-80% humidity produced the best growth and the highest reproduction rate (Georg, 2004). In Romania, Duşan (2013) found that the optimal humidity would be of 82.5% (Table 2), or, if empirically controlled, it can be tested by collecting the manure in the hands and squeezing it, this action should result in a few drops running through the fingers, if the humidity level is appropriate.

Aeration

Aeration is a basic factor in growing earthworms by allowing the air to enter their habitat. Therefore, it should be taken into consideration, when preparing the bedding, for the bedding material to be porous, and if there are cases in which aggregated material is used as food, then this material should be placed either in the middle or at the edge of the bedding in order to allow ventilation through the sides. The earthworms should be disturbed as little as possible, but once a month, the first layer at the surface, down to 8-10 cm should be aerated with a fork, while taking care not to go deeper than that (Duşan, 2013).

Table 2. Action of earthworms in the habitat, depending on the pedoclimatic conditions (Duşan, 2013)

	Senescence	Lethargy	Produces only humus	Reproduction reduced to a minimum	Optimal conditions	Reproduction reduced to a minimum	Produces only humus	Lethargy	Death
pH level	6<	6	6.5	6.8	7	7.2	7.5	7.8	<7.8
Temperature (°C)	0<	0-7	7-14	14-19	19-20	20-27	27-33	33-42	<42
No. of hatchlings in the cocoon		-	-	2-10	10-20	2-10	-	-	
Humidity (%)	70<	70	75	80	82.5	84	88	90	<90

As far as the pH level is concerned, the best range would be of 6.8-7.2 with a neutral reaction, if the pH is too acidic, their acidity can be reduced by the scattering of calcium carbonate, and if it is alkaline, it can be reduced by washing with water or by adding grounded peat (Duşan, 2013). Other researchers say that earthworms can survive in a pH range of 5 to 9 (Edwards, 1998). Eitherway, most experts believe that earthworms prefer a pH of 7 or slightly higher, but those in Nova Scotia have found that the range of 7.5 to 8 is the optimum range (Georg, 2004).

In regards to the salt content, earthworms are very sensitive to sodium, preferring a sodium content of less than 0.5% (Gunadi et al., 2002).

Temperature

The optimal temperature in which the earthworms are most active is around 20°C, respectively between 15°C and 20°C. At temperatures below 0°C the earthworms die but the cocoons can withstand up to -20°C and can withstand this temperature for a long time until the conditions allow the hatchlings to come out. If the temperature is too high, of 30°C and above, it will cause the earthworms to leave the bedding and if they cannot leave it, they will die (Munroe, 2007).

Stimulating the reproduction

When the earthworm population's density becomes higher than 5 kg/m^2 the need for reproduction begins to slow and a fierce competition for food and space occurs. Although it is possible to obtain a population density of even 20 kg/m^2 (Edwards, 1999), the most common densities found in practicing vermicomposting are between 5-10 kg/m^2. Earthworm growers usually tend to practice a density of 5 kg/m^2 (Bogdanov, 1996) and then "split the beddings" where density has doubled, while assuming optimal reproduction densities have been exceeded from that point onwards.

In terms of the food used as a stimulant in reproduction, the following foods are mentioned: fresh horse manure, rabbit or young cattle manure in weighed amounts, sugar-sweetened water (a small cup of sugar for 3 liters of water) that is sprinkled on 2 m^2 every 3-4 days (Duşan, 2013). Sexual maturity in earthworms occurs after 60 to 90 days (Table 3), but reproduction itself begins only after 7-10 months (Duşan, 2013).

Table 3. Earthworm life cycle (Duşan, 2013)

Parent copulation		Cocoon laying		Hatchlings emerging from cocoons		Appearance of the clitellum		Full adulthood/ maturity		End of the cycle
↑	7-10 days	↑	14-21 days	↓	60-90 days	↑	7-10 months	↑	over 15 years	↑
					Earthworm reproductive organ development					

RESULTS AND DISCUSSIONS

The vermicompost, the same as the conventional compost, offers many benefits to agricultural soil, including increased water retention capacity, improved nutrient retention, improved soil structure, and enhanced microbial activities (Munroe, 2007).

By using it, the vermicompost helps to improve the physical, chemical and biological properties of the soils. It contributes in increasing the soil's porosity and respectively in increasing the diameter of the pores in the soil from 50 to 500 μm, which results in better aerohydric conditions for crops (Marinari et al., 2000). It also contributes to stabilizing the soil's reaction, increasing the microbial population and the enzyme activities in the soil (Makeswarapa et al., 1999).

Accessibility of nutrients for plants

Atiyeh et al. (2000) discovered that a classical compost is richer in ammonium, whereas the vermicompost tends to be richer in nitrates, which is the most accessible form of nitrogen for plants.

Similarly, Hammermeister et al. (2004) indicated that "vermicompost has higher N availability than the conventional compost on a weight basis and the supply of several other plant nutrients".

Other researchers (Short et al., 1999; Saradha, 1997; Sudha & Kapoor, 2000) found that the supply rate with more nutrients, including phosphorus, potassium, sulfur and magnesium became higher through vermicomposting compared to the conventional composting.

The analyzes carried out in 2012 on the vermicompost produced in Romania showed the following values: pH - 7.8, humidity (%) - 62.74, organic matter (%) - 82.09, humus (%) - 32.30, ash (%) - 17.91, total N (%) - 1.68, total P_2O_5 (%) - 1.44, total K_2O (%) - 1.42 (Panici, 2012).

Table 3. Nutrient content of vermicompost and compost (Nagavallemma K.P. et al., 2004)

Nutrients	Vermicompost (%)	Compost (%)
pH	7.0-7.5	6-7.2
Organic carbon	9.8-13.4	12.2
Nitrogen	0.51-1.61	0.8
Phosphorus	0.19-1.02	0.35
Potassium	0.15-0.73	0.48
Calcium	1.18-7.61	2.27
Magnesium	0.093-0.568	0.57
Sodium	0.058-0.158	<0.01

It appears that vermicomposting tends to lead to higher levels of availability of most nutrients for plants, than the conventional composting process does.

The level of benefic microorganisms

Specialised literature has less information on this topic than on nutrient availability, but it is believed that the vermicompost far exceeds conventional compost with respect to beneficial microbial activity levels. Clive Edwards of Ohio State University (Edwards, 1999) stated that the vermicompost can have 1,000 times more microbial activity than conventional compost, although this figure is not always attained. The vermicompost plays a role in transforming nutrients into forms that are easier to process by plants in comparision to the conventional compost.

The ability to stimulate plant growth

Atiyeh et al. (2000) carried out a thorough examination of the literature on this phenomenon. The authors said: "Most of these studies confirmed that vermicomposts have beneficial effects on plant growth. Vermicomposts, whether used as soil additives or as components of horticultural media, improved seed germination and enhanced rates of seedling growth and development." These beneficial effects on plant growth showed to appear independently of nutritional transformations and availability, increasing plant growth and productivity rates more than it would be possible through simple nutrient conversion of minerals in more available forms for plants. This is the area where most interesting and exciting results have been obtained. Many researchers have found that the vermicompost stimulates the subsequent growth of plants even when plants already receive optimal nutrition (Munroe, 2007).

Ability to suppress diseases

In recent years, a considerable number of tests have been made regarding the vermicompost's ability to protect plants against various diseases. The theory behind this statement is that high levels of beneficial microorganisms in the vermicompost protect plants by competing with pathogens for available resources, while also blocking access to the plant's roots by occupying all available spaces. This analysis is based on the concept of "soil trophic, a soil-based approach (Munroe, 2007). Edwards and Arancon (2004) show that, through the research of vermicompost commercial products for plants attacked by: *Pythium* on cucumbers, *Rhizoctonia* on greenhouse radishes, *Verticillium* on strawberries and *Phomopsis* and *Sphaerotheca fulginae* on grapes, the incidence of diseases decreased significantly. The authors continue to say that pathogen suppression disappeared when the vermicompost was sterilized, indicating that the mechanism involved was the microbial antagonism.

Ability to reject pests

Research in this area is relatively new and the results so far have been inconsistent. A theory is advanced by George Hahn, a vermicompost producer in California, who claims that his product rejects many different insect pests. He believes this is due to the earthworm's production of the chitinase enzyme, which decomposes chitin from insect exoskeleton. However, the independent testing of its product has produced inconsistent results (Biocycle, 2001; Edwards & Arancon, 2004).

CONCLUSIONS

Earthworms play an extremely important role in counteracting the loss of biodiversity. They increase the number and types of microbes in the soil by creating conditions in which these creatures can grow and multiply. The earthworms's intestine has been described as a small "bacteria factory", expeling more microbes than it igests.

By adding vermicompost and earthworm cocoons on the farm's soil, the microbial community of the soil largely multiplies itself. This underground biodiversity is a basis for an increased biodiversity above ground, as soil creatures and the plants that they help to grow are at the heart of the entire food chain.

By growing earthworms, many of the environmental problems can be solved. Their ability to consume all that is biodegradable can help in getting rid of many environmental waste (manure from livestock farms, sewage sludge, leaves and dry grass, sawdust from nonaromatic wood, paperboard and paper).

The vermicompost has a positive effect not only on plants but also on the soil. It greatly improves the soil structure, decreasing its density, increasing the porosity and absorption of nitrogen from the atmosphere. It thus remedies the soils affected by the long-term use of chemicals. Another advantage is given by the suppression of harmful fungi in the soil. These microorganisms produce hormones, vitamins, nutrients, enzymes, amino acids and minerals needed for plants.

Plants treated with vermicompost have a well-developed immune system, making them more resistant to disease and pest attacks.

Moreover, the vermicompost is the only fertilizer accepted in the European Union as an amendment in organic farming.

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REFERENCES

Atiyeh, R.M., Subler, S., Edwards, C.A., Bachman, G., Metzger, J.D. and Shuster, W. (2000). Effects of vermicomposs and composts on plan growth inhorticultural container media and soil. In *Pedobiologia, 44*. 579–590.

Bogdanov, P. (1996). *Commercial Vermiculture: How to Build a Thriving Business in Redworms*. Ed. Vermico Press, Oregon.

Cracas, P. (2000). *Vermicompostare în stil cubanez.* Compediu despre râme, No. 25.

Dominguez, J. & Edwards, C.A. (1997). Effects of Socking Rate and Moisture Content on the Growth and Maturation of *Eisenia andrei* (Oliogochaeta) in Pig Manure. *Soil Biol. Biochem., 29*(3,4), 743–746.

Duşan, P. (2013). *Practical guide: Earthworm farming*. Ed. Măiastra, Târgu Jiu.

Edwards, C.A. & Lofty, J.R. (1972). *Biology of Earthworms*. London: Chapman and Hall Ltd.

Edwards, C.A. & Arancon, N. (2004). Vermicomposts Suppress Plant Pest and Disease Attacks. In Rednova News: http://www.rednova.com/display/?id=55938.

Edwards, C.A. (1998). *The Use of Earhworms in the Breakdown and Management of Organic Wases* (pp. 327–354). In: Edwards, C.A. Ed. Earthworm Ecology. St. Lucie Press, Boca Raton.

Edwards, C.A. (1999). Interview with Dr. Clive Edwards. In: Casting Call; Peter Bogdanov, Ed. VermiCo, Merlin, Oregon 4(1), June Issue.

Gaddie, R.E. (Senior) & Douglas, D.E. (1975). *Earthworms for Ecology and Profit*. Vol. 1, Scientific Earthworm Farming. Bookworm Publishing Company, California.

Georg (2004). Feasibility of Developing the Organic and Transitional Farm Market for Processing Municipal and Farm Organic Wastes Using Large-Scale Vermicomposting. Good Earth Organic Resources Group, Halifax, Nova Scotia. Available at: http://www.alternativeorganic.com.

Gunadi, B., Charles, B., Edwards, C.A. (2002). The growth and fecundity of *Eisenia fetida* (Savigny) in cattle solids pre-composted for different periods. In *Pedobiologia, 46*. 15–23.

Hammermeister, A.M., Warman, P.R., Jeliazkova, E.A., Martin, R.C. (2004). Nutrient supply and lettucegrowth in response to vermicomposed and composted catle manure. Submitted to Bioresource Technology, December.

Md. Abul, Kashem, Ashoka, Sarker, Imam, Hossain, Md. Shoffikul, Islam (2015). Comparison of the Effect of Vermicompost and Inorganic Fertilizers on Vegetative Growth and Fruit Production of Tomato (*Solanum lycopersicum* L.). Open Journal of Soil Science, 2015, 5. 53–58. Published Online Feburary 2015 in SciRes. http://www.scirp.org/journal/ojss; http://dx.doi.org/10.4236/ojss.2015.52006.

Mila, M.P. (2010). *Research paper on vermiculture and vermicomposting undertaken by bachelor of secondary education, biological science major third year students at Ramon Magsaysay Technological University, San Marcelino, Zambales.* In Partial Fulfillment of the Requirements for Major 6 (Ecology).

Munroe, G. (2007). *Manual of On-Farm Vermicomposting and Vermiculture.* Available at: https://www.researchgate.net/publication/268254767_Manual_of_On-Farm_Vermicomposting_and_Vermiculture.

Nagavallemma, K.P, et al. (2004). Vermicomposting: Recyclinng Wastes into Valuable organic fertilizer. *Global Theme on Agroecosystems*, *8*. 1–2.

Radovich, T., Smith, J., Render, A., & Deenik, J. (2007). *Vermicompost in Hawaii: Its Production and Use.* College of Tropical Agriculture and Human Resources, Virtual FieldDay. http://www.ctahr.hawaii.edu/sustainag/video/vermicompost_r.html.

Rink, R. (Editor), van de Kamp, M., Wilson, G.B., Singley, M.E., Richard, T.L., Kolega, J.J., Gouin, F.R., Laliberty, L.Jr., Kay, D., Murphy, D.W., Hoitink, H.A.J., Brinton, W.F. (1992). *On-Farm Composting Handbook*. Natural Resource, Agriculture and Engineering Service (NRAES-54), Ithaca, NY.

Saradha, T. (1997). The culture of earthworms in the mixture of pond soil and leaf litter and analysis of vermifertilizer. *J. Ecobiology, 9*(3), 185–188.

Short, J.C.P., Frederickson, J., Morris, R.M. (1999). Evaluation of traditional windrow-composting and vermicomposting for the stabilization of wase paper sludge (WPS). In Diaz Cosin, D.J. Jesus, J.B. & Trogo D. (Eds), 6th International Symposium on Earthworm Ecology, Vigo, Spain, 1998. *Pedobiologia, 43*(6), 735–743.

Sudha, B. & Kapoor, K.K. (2000). Vemicomposting of crop residues and cattle dung with *Eisenia fetida*. In *Bioresource Technology*, 73, 95–98.

***Biocycle, 2001. *Vermicompost as Insect Repellent.* Jan 01, 19.