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Vermicomposting

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1. Introduction

Million tons of organic wastes are disposed in landfill or incinerated annually. Each of these methods can make threat to environment and public health by emission of various pollutants to atmosphere, water resources and soil. Also, gathering, landfill or incineration of organic wastes imposes heavy costs to responsible organizations. In wastes landfill in addition to its restrictions such as costs and ground occupying for a long time, odor, flies and rodents, there is a threat of nitrate and other contaminants infiltration to groundwater (Primo et al., 2009; Sawyer, 1978). Air pollution is a problem in many parts of world and a loud alarm for health safety. Although waste incineration almost exterminates the organic wastes and may be a source for thermal energy, but air pollution is its serious threat and nowadays health and environmental protection organizations set so narrow emission standards and approach to these standards in landfill and incineration is costly and with some technical difficulty. Herein challenges for solving the problem of organic wastes safe disposal a biological environment friendly method can be a reliable response. For a long time composting is applied as a biological process of organic waste in many parts of world and in recent decades using some species of red worms in compost process as vermicomposting makes many advantages for the process of organic wastes biological degradation and for the finally obtained fertilizer. The organic wastes passing through the gut of the earthworm, recycled organic wastes are excreted as castings, or worm manure, an organic material rich in nutrients that looks like fine-textured soil (Dickerson, 2001).

2. Importance of vermicompost

Organic waste and especially fast degradable food waste is a considerable fraction of municipal agricultural and some industrial wastes. In many countries food waste is a big part of daily produced municipal wastes for an example the result of a study showed that Iran has a potential for production of 4 million tons compost from municipal solid wastes, annually (Faraji, 2007). Nowadays, public understanding of vermicompost process increased and its deployment to convert organic waste into vermicompost has been increasingly expanded (Tejada et al., 2009). Ease of the vermicompost process and ability of its application in various scales made the vermicomposting a popular issue almost everywhere. This developed application of vermicompost requires much knowledge of the process and its effect on quality of the obtaining fertilizer from the raw waste.

3. Vermicomposting, advantages and limitations

In vermicomposting, worms are feed by organic wastes and the worms change it to fertilizer. In this process, by feeding the worms with organic materials, some of the bacteria that have useful role in decomposition of organic wastes, added to them and expedite the organic materials' decomposition. Also these bacteria have positive effects on stabilization and making minerals applicable for plants (Asgharnia, 2003; William, 2000). Positive effect of adding vermicompost to soil for tomato had shown by Federico (Federico et al., 2006). In another research the increasing growth of rice stalks and soil fertility obtained by adding vermicompost (Jeyabal and Kuppuswamy, 2001). The worms used in the process can also as a byproduct in the process are discussed because; they do grow and multiply during the process and these organisms can used for produce various products, especially in the production of poultry and fish meal. Each earthworm body is composed of about 60-70% of protein and has much levels of essential amino acids like methionine and Lysine which the quantities is even much than livestock and fish. Worms body are consists of 6-11% fat, 5-21% carbohydrate, 2-3% minerals and some vitamins, particularly niacin and vitamin B12 are notable (Edwards, 1985). The worms' activity has negative effect on pathogens and some researchers have shown that the vermicompost is healthier than other organic fertilizers such as compost and manure (Asgharnia, 2003). Some problem associated with vermicompost is about the worms, the worms are sensitive to pH, temperature and moisture content which must be controlled during the process.

4. The worms of vermicomposting

4.1 The worm genus for vermicomposting

There are More than 3000 species of earthworm in the world which roughly found in most parts of the planet (Cook, 1996). Among these species, the ability and play an active role of *Eisenia foetida* to convert waste to vermicompost has been proven in many studies (Bansal & Kapoor, 2000). Other species of red worms or red wigglers such as *Lumbricus rubellus*, *Perionyx sansibaricus*, *Perionyx excavatus*, *Eisenia andreii* and some other species successfully are used in vermicompost production. They often found in aged manure piles, they generally have alternating red and buff-colored stripes and prefer the compost or manure environment. While common garden or field earthworm species such as *Allolobophora caliginosa* prefer ordinary soil and occasionally found in compost pile (Dickerson, 2001).

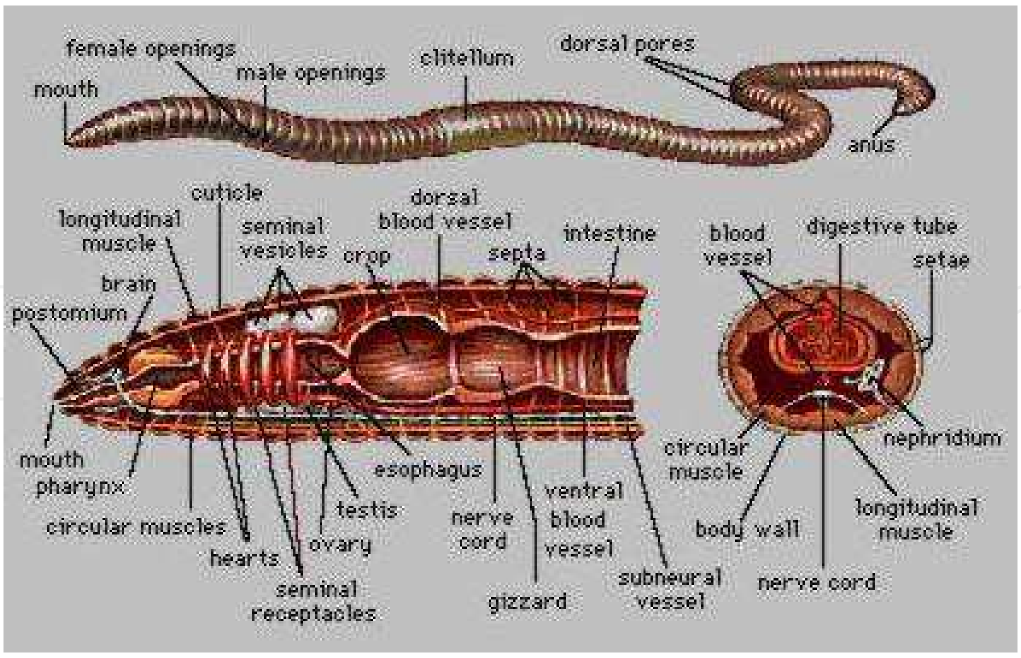
4.2 Physiology of worms and its life conditions

Earthworm body is almost cylindrical shape but may has end cross-sectional area of quadrilateral, octagonal or trapezoidal and in some species may be flat shape. Body length varies from 15 mm to 300 mm and its diameter varies from 1- 10 mm. External grooves, Furrow, on the worm body specify the place of internal curtains ‚Septa‚. These curtains divide the body into a series of similar parts which called Somite or Metamere. External secondary grooves, Annuli, often form three rings. The secondary grooves is a virtual division and do not exist in internal anatomy of the body. The first body segment, Peristomiom, surrounds the mouth and on the dorsal area has a lobe which called Prostmium. How to connect the mouth and Prostmium in earthworm is variable depending on the species and are used for their classification. Earth worms are androgyny and have

both male and female reproductive system which is mainly limited to the front parts of body. Earth worms have a simple digestive system. Earthworms eat almost everything such as plant roots, leaves and seeds, microscopic organisms such as protozoa, Larvae, the Rotifers, bacteria, fungi, and larger animals, especially cattle, feces. The food ingested with soil and passes along from the earthworms digestive canal. Earth worms continuously or semi-continuous are do egg-laying most often along the year. Worm eggs are placed in the cocoon. The cocoon shape is different depending on the species of worm. In moist conditions and the temperature of 16 to 27 ° C for the eggs, within 14 to 20 days the small worms come forth. Natural life of many earthworms is short and some species in case of being protected from natural hazards live longer more than 1.5 Year.
Activity, metabolism, growth and reproduction of worms are strongly affected by the temperature. Temperature and humidity usually have an inverse relation. High temperature and dry environment are more limiting than low temperatures and water saturated environment, for the worms. Earth worms setting cocoon and coming out of egg are also affected by temperature. For example, setting cocoon in *Eisenia foetida* increases linearly with increasing temperature from 10 to 25 ° C, although the number of worms per cocoon out in 25°C is less than 20 °C. Cocoon opening period also is depends on temperature. Growth of new worm out of the eggs to mature at 18 ° C reaching in 9.5 weeks and at 28 ºC only 6.5 weeks is needed (Gupta, 2004).
Worms are sensitive to hydrogen ion concentration which is stated as pH. According to sensitivity to pH in some texts have been divided them in three categories: resistant to soil acidity, sensitive and to soil acidity and a variety that can live in wide range of pH. However, many researchers have expressed that more species of earthworms show interest to live in neutral pH. *Eisenia foetida* is preferred life in the soils that pH is between 7 and 8.
The role of organic carbon and inorganic nitrogen for synthesis of cell, growth and metabolism is essential in all organisms. Proper ratio of carbon to nitrogen is needed for optimal growth of earthworms.

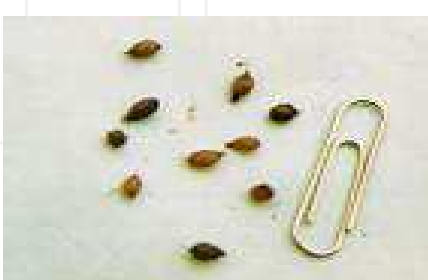
5. The methods of vermicomposting

There are two major methods of vermicomposting, vermicomposting in bin and vermicomposting in vermicompost pile. The bin method is prepared to use in small scale such as home composting, in kitchen or garage and so on. The bin can be made of various materials, but wood and plastic ones are popular. Plastic bins, because of lightness, are more preferred in home composting. A vermicompost bin may be in different sizes and shapes, but its height most be more than 30 cm. bins with a height of 30-50 cm, and not so more than it, are prefect. Draining some holes in bottom, sides and cap of bin is so helpful to aeration and drainage. Around 10 holes with 1-1.5 cm in diameter is a good choice. Before feeding the worms by wastes it's needed to apply a worm's bed. A height of 20-25 cm bedding is appropriate. It may be a mixture of shredded paper, mature compost, old cow or horse manure with some soil.
Pile method mostly is used for vermicomposting in larger scale rather than bin method. Where the vermicompost is the chosen way to processing a Large amount of wastes, application of piles is cost beneficial. The piles can be made in porch place like greenhouse or in a floor with some facilities for drainage in warm climates. Although the pile size may be so various in width and length, however, it can't be so high and is better to follow the height of bin method.



(a)

(c)



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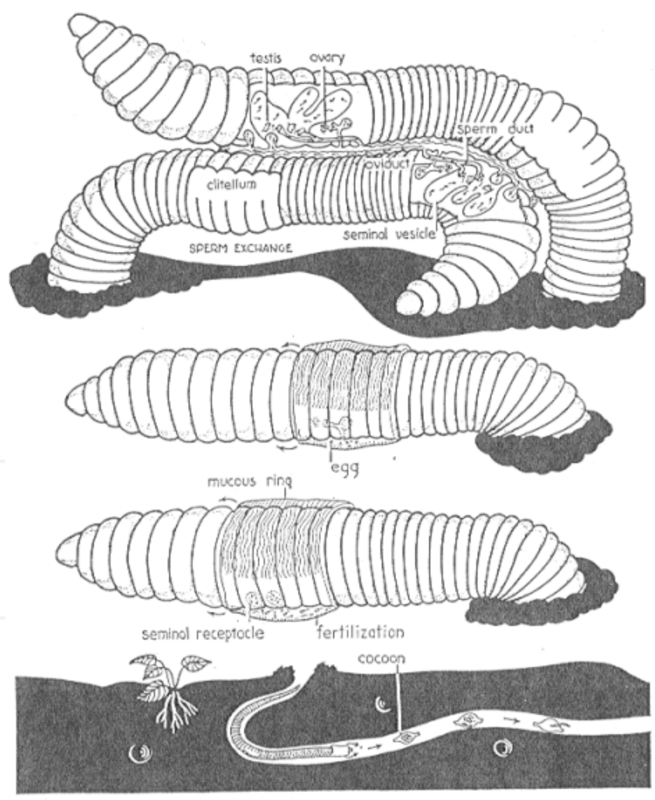

(b)

Fig. 1. a and b, show the worm's body anatomy, intercourse and c and d shows the cocoon (Vermica, 2008).

6. The effect of ambient conditions and wastes on vermicompost

6.1 Effect of temperature

According to kinetics of biochemical reaction and amount of energy production in bio organisms, biological activity is depended on temperature. Bacteria activity is greatly depended on temperature. It plays a vital function in compost and vermicompost process. Also, the worms' activities are widely affected by temperature. Whole the process which named vermicomposting indeed is playing natural role of worms and bacteria in their life to live. So, this process depends on temperature. We know that the bacterial activity multiplies by two per each 10°C increase in temperature and the worms have well activity around 15-30°C. Several studies showed that a temperature range around 15-25 °C is more appropriate for vermicomposting. The most decrease in carbon percentage and C:N ratio have obtained in this range of temperature in a study among three temperature ranges of 5-15, 15-25 and 25-35°C. Also it has been the best temperature for the worms' growth (Rostami et al., 2009.a).

6.2 Effect of moisture content

The bacteria need water to proceeding biochemical reactions and many of essential substances are solved in water for transmission through membrane into bacterial cytoplasm. It's known that, the bacterial activity extremely decreases in a moisture content lower than 40% in a composting process and it almost stops in lower than 10% (Tchobanoglous et al., 1993). Also we know, the worms need to be in a moist ambient because they need to keep their skin wet for respiration through it. Recommended moisture for bacterial activity in compost process is around 55%, but the worms need some more moist to have their maximum growth and activity. It's known that, there is a relationship between moisture content and temperature in effecting on vermicompost process. In a comparative study on vermicomposting process and the worms' growth in various ranges of temperature and moisture, results showed 65-75% is a suitable range of moisture for all ranges of vermicomposting temperature (Rostami et al., 2010. a).

6.3 Effect of pH

Many kinds of bacteria can live in low pH and some live in a pH as low as 2 or even lower. Other kinds of microorganisms which are active in compost and vermicomposting are fungi which can keep their activity in lower pH around 4. Also some bacteria tolerate higher pH than neutral. However, recommended pH range for compost is around 6.5-7.5. In vermicomposting the worms are sensitive to pH and they don't tolerate a wide range of pH and they prefer neutral pHs. Although, some studies showed that the worms can be alive in some higher or lower pHs, but the recommended pH for vermicomposting is around 6-7 (Dickerson, 2001). In lower pH the bacterial activity decrease and worms which don't like it will escape to a place with better condition if they can find or most probably die.

6.4 Effect of C:N ratio

The major effect of C:N ratio in vermicompost is on bacterial activity, high C:N ratio decrease bacterial activity because of nitrogen shortage that is essential for bacteria and takes part in proteins, amino acids and other structural substances of bacteria. On the other hand low C:N ratio will led to loss of the nitrogen as in form of NH_3 to atmosphere. The worms also hate the high concentration of ammonia and will escape from it. Vermicompost process will progress properly by starting the process with a C:N ratio around 25-30 and it will decrease during the process. Carbon reduces because heterotrophic bacteria use organic material as source of electron and carbon is oxidized to CO_2 and releases to atmosphere (Tchobanoglous et al., 1993). However, bacterial nitrogen usage is so less than carbon and some kind of bacteria can stabilize atmospheric nitrogen into compost such as Rhizobium. Also, autotrophic bacteria use ammonia as source of electron and convert it to nitrite and nitrate which remain in compost unless an anoxic condition occurs. In this condition nitrate and nitrite reduced and nitrogen releases to atmosphere as N_2 (Bitton, 2005).

7. Effect of preparation time on vermicompost

Before feeding the worms with organic waste materials, organic materials are composted for a while without worms. This causes the of organic matter decomposition spent thermophilic level and the worms which are sensitive to high temperature will not damage. Also, the compost production process forward faster, and many of pathogens are destroyed in thermophilic phase. Duration of the preparation is impressive on quality of the resulting compost, vermicomposting process and space and facilities needed for preparation. Results of some studies showed that a nine-day preparation is proper (Nair et al. 2006). This time seems to be enough for pass the initial composting thermophilic period and also for loss of most pathogens (Bansal & Kapoor, 2000). In another study, the impact of preparing time on vermicompost was investigated in food waste that no amendment had been made on it (Rostami et al., 2009. b). Sometimes for better aeration or adjust C:N ratio the balking agents or other materials, such as wood chips, sawdust, manure, sludge and so on may be added to wastes as amendment. In this study, food wastes with preparation time of 0, 6, 12 and 18 days has entered in Vermicompost process and were monitored during the process. Results showed that, duration of preparation is effective on changes in C:N ratio during the vermicompost process. Best results and lowest C:N ration obtained along 6-12 days of preparation. Fig. 2 is presentation of the result. In this kind of not amended materials more preparation duration may redound on anaerobic process and as a result of the acidification phase, pH is reduced and these conditions are unfavorable for worms to live and activate. Thus, reducing the activity of aerobic bacteria and worms, the C:N ratio reducing speed is decreased. Fig. 3, Shows the trend of pH reduction consistent with increased preparation duration. It's clear that, if sufficient aeration and well composting conditions provided during preparation by material amendment, aeration or by any means, anaerobic condition will not occurs in longer preparation duration. But it needs proficiency and some cost.

8. The effect of worm population on vermicompost

In vermicompost process the worms have a vital function. So, the worms' population in waste is effective on vermicompost process and quality. So, a question about vermicompost is, how many worms most be applied for vermicomposting to get a prefect process and fine vermicompost? Some researchers have done efforts to find the answer. It is clear that, each species of worms have individual properties and the answer may be different. Some

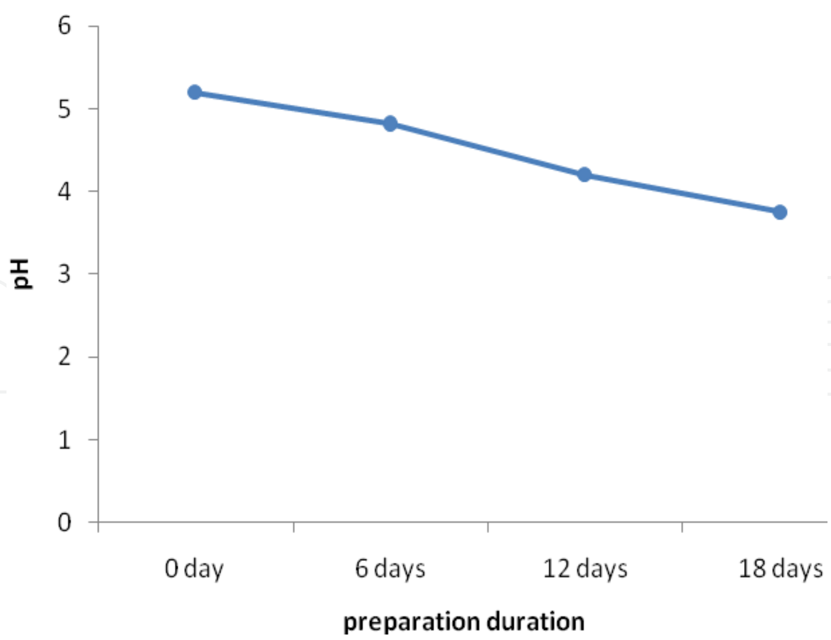

Fig. 2. Mean pH of the wastes with various preparation durations, within vermicomposting process.

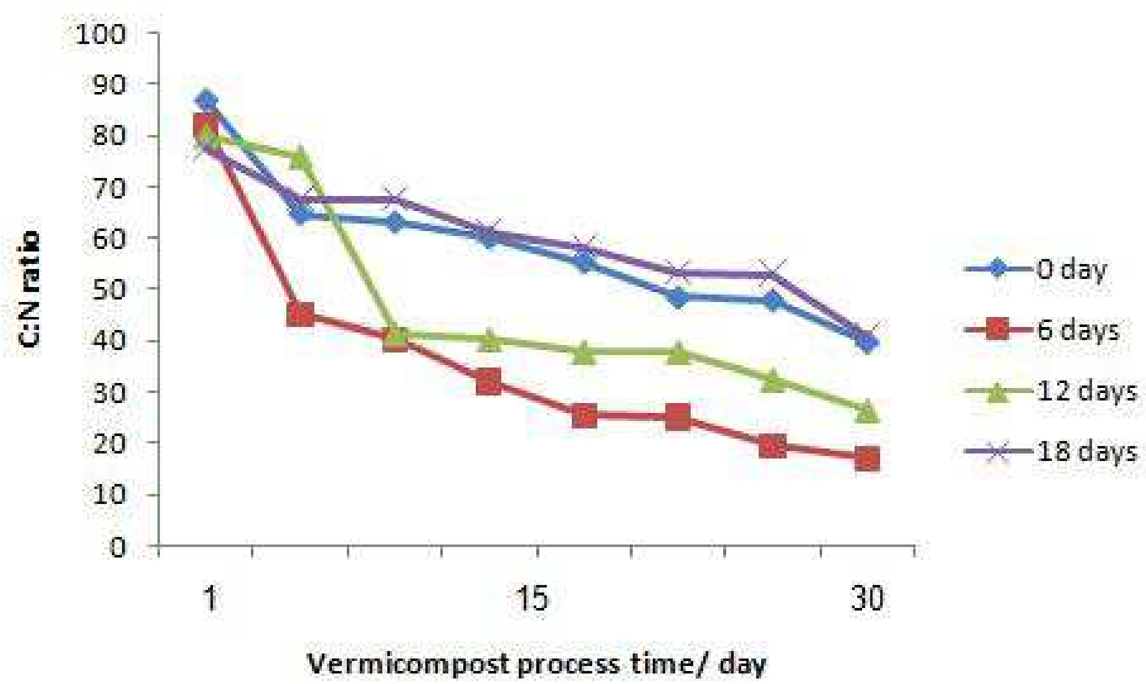

Fig. 3. C:N ratio during vermicomposting process for wastes with the various preparation durations.

studies declared that a worm can eat around as much as half weight of its body per day (Jicong, 2005). Also, some texts suggest a 1:1 ratio of worms and wastes, by weight, for vermicomposting. In a study the effect of *Eisenia foetida* species population was investigated on vermicomposting of food waste. In this study four populations of worms including, 6, 12, 18 and 24 worms set in 70g of food waste and a blank, food waste with no worm, were monitored for a month of vermicomposting. The results showed that, increasing in number of worms can be effective in maintenance of pH around neutral range. It is important during vermicomposting process. Also, it is important for the obtaining vermicompost to be at the standard range of A class's range, 6.5-8.4, (Brinton, 2000). More number of worms can much aerate the waste and prevent process from anaerobic condition which reduces pH. Also, in aerobic condition ammonia is consumed and this can prevent from much pH increasing. Best result about C:N ratio in this study has seen in the population of 18 worms per 70g of waste (Rostami et al., 2010. b). According Fig. 4, the C:N ratio declined with increasing of worm population until 18 worm and then increased in population of 24 worms. This result may be due to no more increasing of number and activity of bacteria in presence of more worms, or slaking of worms' activity which some limiting factors such as food or other factors can be causes of that.

9. Application of vermicompost

Vermicompost can be applied everywhere which wanted to help nutrition and growth of plants. There are many reports of vermicompost successful application for various plants. There are many methods to add a fertilizer. A simple method for using vermicompost is adding it as a thin layer to soil around the plant and mixing with the soil. It is very mild and overfertilizing will not result in burning the plant. Amount of using vermicompost depends on its quality and containing elements. But, there are some recommended normally amounts for different plants. An example is table 1. Period of fertilizing can be 2-6 month according to plant's demand.

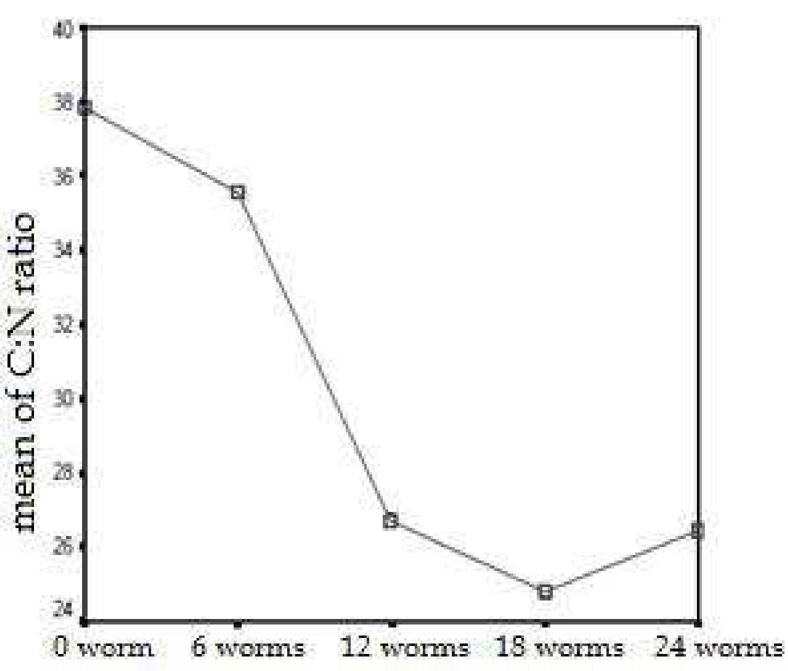

Fig. 4. The mean C:N ratio of vermicompost with various worm population.

10. Vermicompost tea

The vermicompost tea is a mixture of aerobic microorganisms which extracted form vermicompost in highly aerated water. This liquid contains beneficial bacteria and fungi which help to enrich the soil, which may be poor of microorganism in result of pesticide and inorganic fertilizer application, with these microorganisms. The aerobic microorganisms also are disease-suppressive for plant. It most noted that the leachate of vermicompost during vermicomposting process is not tea it is just vermicompost leachate and may contains significant amount of not decomposed organic material.

Plant	Amount of vermicompost (g)
Fruit Tree	1000-3000 According to age of the tree
Per each sapling and seedling forestry tree	100
Per each square meter of ornamental shrubs and grass	500
For ornamental plants, per square meter (flower types)	400
For each pot ,The average pots	80
For each pot, The Large pots	150

Table 1. Amount of vermicompost that is applied for plants

10.1 Method of tea making

The tea making commonly is performed by using a tea brewer. It is a set which aerate the water and extract tea from compost. There are many kinds of brewers in various sizes and types. Fig. 4 shows a brewer.

Fig. 4. A 100-gallon tea brewer (Ingham, 2003).

It is important to choice an appropriate vermicompost for tea extracting. Whatever the using vermicompost be fresh and contains more microorganism. So, the tea will be better. An incomplete and not perfectly stabilized vermicompost contains not decomposed organic materials that will be cause of quickly turning the tea to anaerobic condition and it poorly contains nutrient and microorganisms than a finished vermicompost. Nutrition of the microorganisms after brewing is substantial to keep them alive. For this purpose something such as brown sugar, honey, and black strap molasses can be added to the tea.

10.2 Advantages and limitations

Vermicompost tea has the nutrients of vermicompost. It is liquid and quickly reaches the plants' root. The tea enriches soil with bacteria and helps to soil bacterial activity. The bacteria cover roots, leafs and stalks' surface and terminate the anaerobic bacteria, pests and pathogens in a compotation. It helps plants to resist against many diseases. A limitation of tea is that, it can't be stored for a long time because bacteria in the tea need food and oxygen. Tea is a liquid rich of bacteria and its food and oxygen demand is high. So, the bacteria will die and tea turns to anaerobic in less than a day unless the food and oxygen provided.

10.3 Tea application

Tea can be applied for various kinds of plants not only for fertilizing but also for protection of plants against diseases and pests. It commonly is applied by spraying onto both sides of plants' leaves and stalk and drenching into the root zone and used as root dip for bare root. It may be applied almost any time, except in cold weather conditions when soil is below 5°C. The UV radiation harms the microorganisms and it's better to avoid times with intense sunlight. Some plants prefer bacteria dominated soil and some prefer fungi dominated soil, it's better to use vermicompost tea for the plants which prefer bacteria dominated soil because in vermicompost tea the bacteria are dominant (Ingham, 2003).

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Integrated Waste Management - Volume II
Edited by Mr. Sunil Kumar

ISBN 978-953-307-447-4
Hard cover, 472 pages
Publisher InTech
Published online 23, August, 2011
Published in print edition August, 2011