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УНИВЕРЗИТЕТ „ГОЦЕ ДЕЛЧЕВ“ ШТИП

NATIONAL AGENCY FOR EUROPEAN EDUCATIONAL PROGRAMMES AND MOBILITY

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USE OF ORGANIC WASTE TO OBTAIN LUMBRIHUMUS

March, 2017

Publisher:
Goce Delcev University - Stip, Faculty of Agriculture

Title:
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Language editor:
Vesna Petrova

Technical editor:
Slave Dimitrov

Suported by:
Erasmus+, Project number 2015-1-MK01-KA202-002855

Project title:
„Developing OER and Blended Modules for Agriculture and Rural Development"

CIP - Каталогизација во публикација
Национална и универзитетска библиотека "Св. Климент Охридски", Скопје

631.86:595.142

MIHAJLOV, Ljupcho
Use of organic waste to obtain lumbrihumus [Електронски извор] / Ljupcho Mihajlov, Liljana Koleva Gudeva. - Stip : Goce Delcev University - Stip, Faculty of agriculture, 2018

Начин на пристап (URL): https://e-lib.ugd.edu.mk/en-678. - Текст во PDF формат, содржи 44 стр., илустр. - Наслов преземен од екранот. - Опис на изворот на ден 16.01.2018. - Публикацијата е во рамки на проектот: "Developing OER and blended modules for agriculture and rural development". - Библиографија: стр. 44

ISBN 978-608-244-476-5
1. Koleva Gudeva, Liljana [автор]
а) Лумбрихумус - Производство
COBISS.MK-ID 105808138

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INTRODUCTION

Environmental protection had become a top subject with continuous efforts to provide best possible results. Most common activities from the point of view of the agronomists is how to produce safe food. Such kind of production is defined by numerous factors with more or less identical importance. However, the use of healthy and qualitative substrate are on the top of the priority list, is a producer wants to obtain products with high quality and safe for human nutrition.

This brochure is to be used by persons who tend to learn how to produce safe food. This procedure is not of a complex nature and can be learned by any individual. Applying the concept will significantly improve the level of food quality, which will result in improving the quality of life by the persons who use safe food in their daily ration. In order to organize production of safe food, it is necessary to organize this process in holistic way, since the soil and the plants possess enormous organic productive potential, yet they, as a system, are quite vulnerable by numerous biotic and abiotic factors.

This document will provide an overview to the possibilities and the benefit of using various organic waste for obtaining high quality organic substrate (manure) created by the processing activity of the worms, especially by the Lumbricus rubellus.

In the nature composting processes occurs continuously, without involving of the human factor, because there is no need for it. The organic substances are in pure natural state and in the nature there is no comes to mix with non-organic waste, so there is no need for selective collection. All those natural conditions offers any needs for obtaining a quality humus, primarily such as land, moisture and sufficient oxygen.

Controlled and organized production of organic compost actually stems from what daily and continually occurs in nature.

Production of high-quality compost containing humus is a starting point improving the systems used for production of ecologically acceptable and healthy plant products.

COMPOST AND COMPOSTING

Composting is the oldest and the most natural way of recycling organic matter. It is a process where the decomposition of organic matter and humification goes to the end, which occurs a dark matter that looks like and smells like a humus. Composting is the process of biodegradation - controlled biological decomposition of organic matter which are contained in organic waste (vegetables, fruits, etc.) mixed with brown mass (dry leaves, branches, etc.) and gardening land with the presence of oxygen, microorganisms and sufficient of humidity (Koleva Gudeva and Janev, 2008).

Compost feeds the soil, improves its structure and it is the best source of nutrients for plants. Composting is the great solutions for both the plants and the environment as well (Ivanov, 2008).

The first device for composting of organic solid waste was constructed in the Netherlands at 1931. Then, after the Netherlands from 1955 to 1965, and other countries with developed agriculture (France, Italy, Israel), also introduced the method of composting (Pashaliski-Andonovska, 2004).

The benefits of composting include:

- Improving soil fertility through its enrichment with humus and adding nutrients to plants, as well as, the long term positive impact on the retention of moisture in the soil;
- Recycling of kitchen and gardens waste, which can be reduced by up to 30% of the home waste quantities which usually goes to waste containers;
- Introducing beneficial organisms in the soil, microorganisms and larger organisms in size such as eg earthworms which replenish aeration of the soil and break down organic material to the plant and mineral forms available to plants;
- The advantages of composting for the environment comprise in offering natural alternative to synthetic fertilizers used in agriculture;
- Reduction of waste which go to municipal landfills due to the fact that about a third of municipal waste could be used for the preparation of compost.

Materials for composting

Almost any matter from organic origin is suitable for composting. It is only necessary an appropriate proportion between the substances rich in carbon (brown) and those which are rich in nitrogen (green). To obtain compost is necessary, above all, mixing of waste material from both groups: brown and green component. The brown component include: dry leaves, dried plants, small dry branches, sawdust, hay and straw, bread, egg shells, ash tree crushed newspapers (in black color) and cardboard. The green components include: debris or waste from vegetables and fruits, fresh (green) leaves, green plants, flowers, hedges.

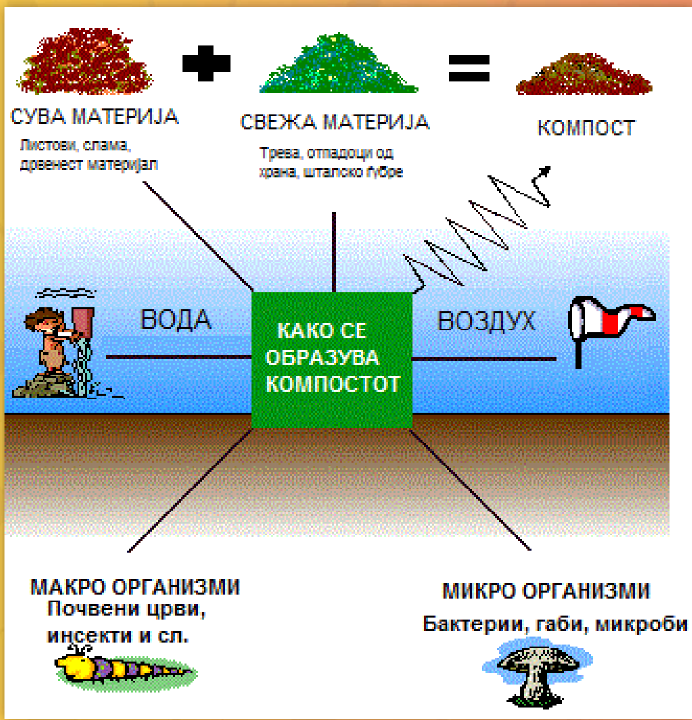


Figure 1. Formation of compost (Mukaetov and Poposka 2013)

Factors that affect the composting process

According to multiple sources of literature the most important factors affecting the process of composting of different organic waste are:

- The size of the particles of the composted material (shredding, smaller portions, but not too small)
- Microorganisms (the classes of bacteria, fungi, yeasts, actinomycetes, algae and protozoa)
- Aeration (oxidation; air enrichment in the center of the composted mixture)
- Porosity (the space between particles of the composted mixture)
- Moisture content (40 – 60%)
- Temperature (30 – 60 oC)
- pH of the composted mixture (optimal pH value = 6,5-7,5)

- Nutrients and ratio of carbon and nitrogen (Appropriate levels of phosphorus and potassium; C: N ratio = 25: 1; brown part : green part ratio = 1,5: 1)
- Absence of toxic wastes (metal pieces, plastic, pesticides, wood treated with chemicals, etc.)..

Stages of composting

The composting process is a process that takes place in several stages. The stages of composting generally can be divided into three, namely:

- Stage of decomposition or mesophilic phase;
- Stage of converting or thermophilic phase, and
- Stage of maturation or cooling phase of the mixture.

The stage of decomposition takes from two weeks up to two months, depending on the degree of aeration, and on the ventilation of bio-waste matter at the compost pile. In the first week the temperature of the material in the compost pile quickly reaches 60-65°C. Then, so-called thermophilic microorganisms multiples and decomposes the sugars, starches, proteins, and then the cellulose. The final products of degradation are water (H2O), carbon dioxide (CO2), ammonia (NH3) and nitrate (NO3), which begins the mineralization of organic matter. At this stage, because of the increased temperature in the compost mixture, (which can reach up to 70°C), pathogens and seeds of many weeds are destroyed.

The stage of converting lasts two up to four months after the phase of decomposition. The duration of this stage depends also on the aeration degree. At these stage begins to intensify the action of fungi for absorbing liberated ammonia, so cannot develop an unpleasant odor from decay. The starting compounds of bio-waste matter are almost completely decomposed. The volume of compost pile is reduced almost by half. Then, the temperature begins to fall down and reaches the 25-35°C.

The stage of maturation takes one month or several months and occurs after the previous stage. The length of this stage depends on the degree of aeration and on the value of outside temperature. Compost pile receives the value of the external temperature from the environment and it starts to inhabit with small animals, worms, centipedes and other small insects. All that small organisms furthers the decomposition of compost matters. Thus are create certain conditions for chemical reactions which occurs at that stable humus mixture. From the compost pile begins to spread smell characteristic for dense forests, typical for mature compost.

COMPOST CHEMICAL COMPOSITION

The types and quantities of waste inputs are potentially important factors influencing the chemical properties of home produced compost. Samples of composted materials collected each year during the dismantling of the compost bins were analyzed for a suite of chemical determinants. The minimum, maximum and the mean values of the chemical properties of compost samples taken at the end of each monitoring year are presented in Table 1. In general, the nutrient contents (Total N, P and K) were larger at home composting than those typically reported for centralized and industrial composting. This could be explained because woody plant remains of low nutrient status are generally excluded from small-scale home composters, which are mainly supplied with only soft plant tissues of higher potential nutrient value as a feedstock for composting (Imperial College UK, 2006).

Table 1. Chemical composition of the compost (Imperial College UK, 2006)

Параметар	Year	Minimum	Maximum	Mean valu
Сува материја (% свежа маса)	1	17.2	63.2	27.9
	2	21.3	75.4	34.8
Органска материја (% dm)	1	7.9	69.3	29.9
	2	6.6	65.3	23.7
pH	1	5.6	8.6	6.8
	2	5.9	9.3	7.4
Вкупно N (% dm)	1	1.1	6.1	3.1
	2	1.5	6.0	3.3
Вкупно P (% dm)	1	0.1	3.4	0.4
	2	0.1	2.4	0.6
Вкупно K (% dm)	1	0.42	4.15	1.88
	2	0.56	2.93	1.20
Вкупно Mg (mg kg^{-1})	1	166.0	626.0	336.0
	2	67.0	265.0	193.0

Scientific facts on humus

There are numerous definitions of humus in nature. The most commonly used standard definition of the professional and scientific community for humus is as follows:

,,The humus is dark soil organic matter produced from decomposed - decaying plant or animal matter, which forms the basis for soil fertility."

The processes of decomposition of organic matter resulting in the extinction of plants and animals encourage and catalyze the living organisms in the soil, mainly the microorganisms. The intensity of decomposition of organic matter is subject to certain conditions (temperature, humidity, aeration and chemical composition of the substrate), the zone of activity of living beings in the soil and the degree of biodiversity of underground life.

In case the processes of decomposition did not complete, i.e. there is no complete oxidation of organic matter (only partial), the humus is created through so called humification process. The chemical composition of humus is complex and varies depending on the site conditions and the type of soil where he creates.

Waksman (1938), describes the humus as amorphous mixture of compounds resulting from the partial decomposition of organic (mostly plants) residues in anaerobic or aerobic conditions in soil compost, peat and water pools. Generated carbon mostly comes from peat, containing many transitional forms of humus in a higher degree of decomposition. This is obtained through microorganisms' activity in decomposing plant debris in the past. The final product of these processes is the stone coal (anthracite). Therefore petty waste from mines charcoal (lignite) can be used as an effective organic fertilizer. Coal in "younger" phase under development include compounds such is the humus.

Figure 2. View of the structure of humus with its functional groups

Humic acids and their salts, Fulvic acids

The basis of humus consists of large organic molecules having colloidal properties (can make colloid in which apart from doing dissolved substances dispersed in the form of relatively large particles, but cannot sediment). Such solutions (that occur in the presence of sufficient moisture in the soil) act as glue that connects the soil particles. So humus improves water regime in the soil making it loose and friable, provides circulation of the necessary amount of air (oxygen) into the soil so that the soil makes the "lighter" and typically more acidic.

Humus originated from the decomposition of living organisms thus contains the necessary amount of nutrients for plant development. The quantities of these nutrients are balanced in ratio which is acceptable to the majority of plants, although usually is closer to the minimum needs of plants. As a result of its structure and chemical composition, the humus has an important ability, acting as a buffer in the soil which is very important in fixing the acidity of the soil. As a result of its structure and chemical composition, the humus has an important capability to acts as a buffer in the soil which is very important in fixing the acidity of the soil. Perhaps more important is the capacity to exchange ions which in nature is found in certain minerals. Of these the most important are zeolites that are currently applied in powder form as a soil enhancer (various "stone flour").

The ability for exchanging the ions is most important for soil fertility. This is identified in the ability of some substances to bind themselves to the ions of other elements but in a way so the plant can release them and use again in their metabolism. The ability of bonding of the copper ions to the soil humus components causes deposition of copper in the surface layer of the agricultural area in which copper preparations are used as fungicides. On the other hand, iron-bound humic substances act against chlorosis in plants even in conditions of high concentration of phosphorus in the soil, although there is antagonism between iron and phosphorus (too much phosphorus prevents passage of ions of iron from the soil).

Humus contains components that interact as e phytohormones in plants. Such ability is very important because it supports the development of plants.

It is proven that plants exploit a portion of organic matter plant directly (humic acids that have small molecules) and extracts of humus added up to the foliar fertilization of the plants.

Humus extracts are also in use as biological preservatives in defense against fungi and bacteria. Also, the insects less attack the plants that are sprayed are sprayed with the extract of humus, as the thin film reduces the excretion of scents that are characteristic of certain plants in which predators have been discovered, thus resulting in reduced insect attack.

Conditions and material from which the humus was incurred determine its properties. So, humus originating from soil rich in alkaline minerals (limestone, and especially dolomite), has a slightly basic properties: pH value is at or above 7. This humus is called mild humus. It is located on the grasslands and deciduous forests.

Soils that have such features, neutral or slightly alkaline reaction, and containing humus are generally known as the most fertile. Composting is a simple way of adding nutrient-rich humus that provide energy for plant growth and renewed vitality of impoverished soils.

The creation of humus in nature is a slow process that constantly takes place where there is organic matter - mostly of vegetable origin in conditions of higher humidity. So topsoil is found at the meadows, under shrubs and forests. Special kind of humus material is obtained from wetland plants with long decay under water without oxygen. Because the origin and washing out of the mineral composition and the constant presence of water, peat has a completely organic composition and does not contain or contains trace nutrient minerals and its positive actions consists only in improving the soil's water regime, the air permeability of the soil and the possible acidification of alkaline soils.

Therefore, it is completely wrong to conclude that plants can be grown and develop well only on peat or with the addition of peat in depleted soils. Due to the good transparency and permeability of such substrate the plants develop in a quite short time, until nutrients are still present, and afterwards lag and soon perish. We should not neglect the role of humus and heat insulating material that slows the temperature changes in the surface layer of soil 20-30 cm in which it is located.

LUMBRIHUMUS

Even in millennia ago it was known of the influence of earthworms fertility on soil's fertility. In ancient Egypt the ordinary rainy worm was celebrated for it role in soil processing. It is impossible to walk through the humid forest or meadow lands and not to notice the traces of the work of worms: these are traces of "work" of earthworms that soil tirelessly drill ducts looking for nutrients in acceptable form for them (half decayed organic substances in the form of slurry or dissolved. Nesvarliviot part they excrete the exits of canals are on the soil surface).

5000 years ago ancient Egyptians knew about the worms. Their laws explicitly prohibited any export of worms taken out from the valley of Nile, because the secret of fertility of that area was obtained from a large concentration of worms in river sediments of the river Nile. Many centuries later one of the greatest scientists Charles Darwin, more than 40 years studied the worms, and he was the first scientist wrote the most complete study of worms to date. Darwin takes a simple conclusion that „All the homeland around the World spent multiple passes through the womb of worms" and he found that worms in nature within one year processed and disposed humus 4 kg per square meter (or 40 tonnes per hectare). Furthermore in his study he found that in the nature there are no other animals in the history of the world that have played such an important role as worms played in creating a worm humus as a fundamental component responsible for basic human existence - food (Naumovski, 2013).

> Namely, those small gluttonous organisms have no teeth, so the feed can only be "slurp" through the oral opening. That is one reason why worms live only in moist areas.

Earthworms are a special group of red worms (Lumbricus rubellus), the class of 3000 species that inhabit the fermented manure from farm animals, hence the first attempts at artificialy breeding the worms (for the hunting of fish) took place on that material. Strains of red worms that inhabit rural fertilizers without intervention of man exist anywhere. These strain of worms have not being specifically explored in experiments on mass cultivation for the production of humus though they spontaneously generate it.

Ordinary earthworm is very timid and restless animal with congenital strong instinct to escape, while the red Californian worm does not escape away, and when there is enough food and other living conditions is not moving away from its relatively small living space. A common feature of all types of worms that do not tolerate vibrations hence the beds should not be kept near a source of vibration.

The reproduction capability of Californian worm versus the common rain worm is much greater. From a bed of 100.000 worms, within a year with proper feeding and breeding almost 18-20 beds can be produced with the same number of worms in each one of them, i.e. up to 2.000.000 individual worms. Theoretically that number could be far greater, even ten times greater. None of the other types of worms does not possess the same ability to create such number of population.

Importance of the worms' reproduction rate in production of humus

Feeding mushy, half-rotted manure and other organic, primarily plant matter, worms eject about 60% of the material in unprocessed form as scum. But this scum known as "red worms' humus" possesses huge potential for growing plants.

With these positive characteristics this kind of humus exceeds by far the best fermented manure. Besides having a porous structure and is well mixed with soil, sand and peat that during metabolism in the body of the worms balances to the most favorable pH, it does not contain pathogens, parasitic bacteria and fungi and is also extremely rich in beneficial saprophytic bacteria and fungi. Small amounts of this humus added to exhausted and biologically inactive soil (in wet conditions) have restored the biological life in it, and thus to accelerate the processes necessary for the development of plants.

During the maturation of the manure that lasts through the year processes of washing-out and evaporation of nutrients appear thus making the manure more acidic and loses in nutritional value. Turning manure into humus by the worms lasts from 3-6 months (depending on its type and maturity). Chemical and biochemical reactions are very useful and economically targeted, there is no excessive washing-outs by the rain and loss of valuable volatile. At the same time, the worms' activity corrects the pH of acidic materials and product neutral reaction.

Hummus with approximately the same properties, the worms produce from other materials, which in their original form cannot be used as a good fertilizer. Some are even lost for use in large quantities and in worse case they are polluting the environment.

During the creation of humus, certainly the most important is the time factor. Human intense activity in the production of food, which is produced and collected a few unnaturally rich crops per year very quickly exhaust the soil. The use of fertilizers and pesticides, burning or removal of the harvest residues, further suppresses the formation of humus.

Worm biology

California red worm (Eisensia foetida) is a strain of worms that are of 5-8 cm depth, red, obtained by artificial selection from the large kind of red worms (Lumbricus rubellus). Both spacies are representatives of the family Lumbricidae part of the big class Oligochaeta. His relatives can be find in nature in animal waste and piles of various kinds of waste. Earthworms (Lumbricus terrestris) differ in the lack of glands that secrete defensive stinking yellow liquid, as for the worms this is the only protection they have from natural enemies.

The body of the worm is a roller with a narrow outlook on both sides. On one side, which is thicker, it is the "head" of the worm with oral whole extending in the throat and esophagus. At the end of the esophagus is the stomach where food is soaking with digestive juices, mechanically squeezed and mixed, and then transferred to the intestine. Then the soluble ingredients of the feed are absorbed through the wall of the intestine and they enter the blood system, while unprocessed scrap arising from food are excreted through the rectum at the end of the body. Exactly this feces is the sought by-product, the humus produced by the worms.

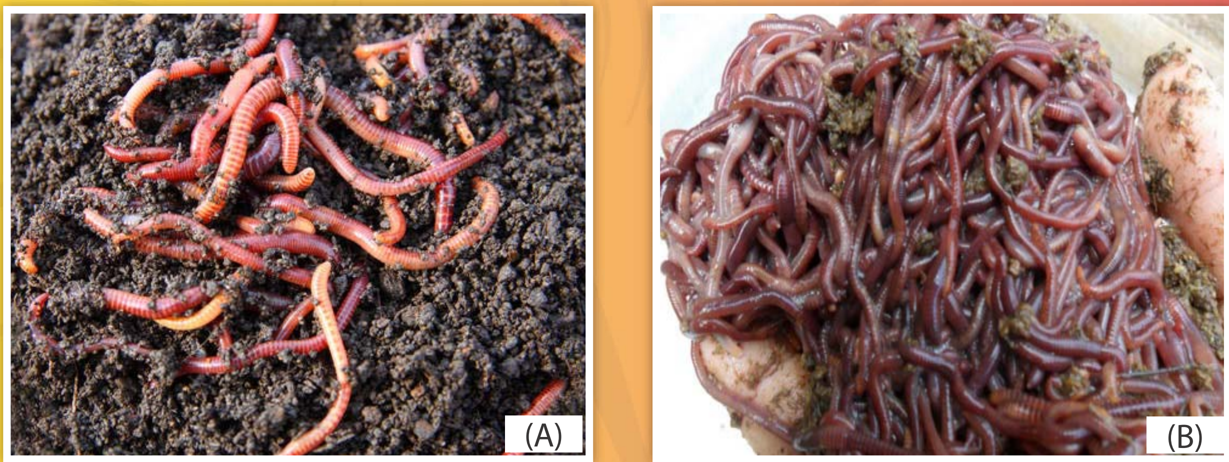


Figure 3. A) California red worms (*Eisensia foetida*),
B) Red earthworm (*Lumbricus rubellus*)

In the stomach there are glands that secrete calcium carbonate needed to achieve the required neutral reaction of the food. These glands play an important role because without them any acidic form of food (inevitable as a product of fermentation) causes a disease known as "protein poisoning."

Of course, the food must contain available and sufficient amount of calcium carbonate so that the worm could consume it and align it with the secretion of the mentioned glands. In nature there is no practical possibility to reach a deficit of calcium carbonate, for each soil (except in very rare cases) contains calcium carbonate.

Due to the described mechanism of regulating the acidity of the nutrients to a neutral reaction (pH 6.8-7.2), the worms' feces i.e. the humus have the same pH, ideal for the development of the root system in the majority of plants.

Ring form body structure of the worm is composed of muscles that allow movement through soil or other materials. On both sides of each ring there are two pairs of hair, bristles that facilitate the movement in the environment. Also, there are glands that are secreting mucus wetting worms' body and maintain external membrane (cuticle) "skin" of the worm moist and supple.

The worms do not possess special breathing organs but breathe through their skin (cuticle). Therefore they need constant moisture of the skin and of the environment. Worms actually use oxygen that is dissolved in the thin layer on the surface of their skin. For that reason the worms do not suffocate when they found themselves in clean water rich with oxygen, but can suffocate in dirty and muddy water in which oxygen is used up for the oxidation of the dirt.

Figure 4. Earthworms. Common earthworm (Lumbricus terrestis) and red earthworm (Lumbricus rubellus) (Cindy, M. Hale, et all, 2006)

With synchronized cramping and stretching of individual muscle ring, the worms are digging holes, making crossings through soil layers and move through them with incredible speed.

Worms show special sensitivity to light. It is awkward for them and is a devastating phenomenon. The light forces them to escape by creeping back into the soil. If forced to expose themselves to sunlight, they experience paralysis and die in short time.

This probably happens because in their skin (cuticle) they do not possess defensive pigments, which will prevent the penetration of light into their inherent translucent tissue, down to the internal organs. This defensive system is deviant but effective because they are constantly inside the dark soil.

That’s why worms are moving on the soil surface only during night time or only when threatened (by flooding the soil with water and suffocation or physical changes in the environment in which they live).

Worms can be forced to get out of the soil by inserting a stick into the soil and by vibration it (shaking). These vibrations and movements are transmitted by soil, received by the existing worms and since these sensation is unfavorable to them, they start moving out of the soil and flee looking for a more peaceful place, creeping back into the soil.

Although worms are with both sexes in one body, it is necessary to mate between individual worms, to transfer sperm from one to another, since they cannot be fertilized by their own semen (it is similar with snails).

What can worms eat?

Composting with worms is a different from the traditional way of composting. Lumbriculture requires no special relationship between the matters which are containing nitrogen and the matters which are containing carbon, such as at the traditional methods of composting.

Manure, consisting of faeces of domestic animals mixed with the material used as litter - litter (typically straw from wheat, straw, wood chips or sawdust and other plant materials suitable shape) certainly is the best food for worms. It should be taken into account that all domestic animals provide fertilizer (manure) equally good for processing into humus.

Horse manure is certainly the best quality material for feeding the worms. It can be put in the bed of worms with no previous preparation or maturation. It is only the addition of water to achieve optimal humidity worms can consume. Characteristics of horse manure are: a high percentage of cellulose and partially decomposed products of horse metabolism enzymes and minerals - so the bed fermentation flows spontaneously, gradually, which prevents it of becoming overheated. It does not contain excessive amounts of sodium chloride (table salt) that would otherwise come from urine. Fresh horse manure has positive impact on the propagation of worms, especially feces in litter linger long time unless they are fed hay and grains, part that usually remains untreated by the animal’s stomach.

The humus obtained from pure horse manure has another feature: it works on accelerating the growth of plants because it contains phytohormone, growth factor, indole-butyric acid (IAA) which is present in the urine and digestive tract in the animal. When horse manure is used it should not be rinsed with water because the concentration of phytohormone remains maximum.

Cattle manure has similar characteristics as the one obtained from the horses, but there are many differences. Firstly, there is rarer consistency, contains a greater amount of urine, and thus more salts that are harmful to the worms. Since cattle are ruminants during digestion of food in the rumen is excreted greater quantity of enzymes and other digestive juices remaining in the feces so manure from cattle is more acidic. Because of this, before giving cattle manure to the worms processing should be applied. To be suitable for feeding the worms it should first be left to mature for several months to a year with occasional overturns of the pile.

Manure from pigs is an environmental problem because of the high content of protein, unprocessed food scraps and minerals. Requires long-term processing and fermentation in special machines that grind the manure, reduce the amount of moisture, thus allow rapid fermentation process. This type of fertilizer in agriculture is unusable due to its very unpleasant smell. If applied to the worms directly, can cause disease known as "protein poisoning. " If you do not intervene in time, such situation can destroy the bed completely.

Manure from poultry (chickens, chickens, ducks, turkeys, etc.) in composition is extremely rich in protein, nitrogen and phosphate. Therefore, it can be used either as base or as food for worms. Even a small amount of the normal food for the worms can cause a "protein poisoning". The fermentation time for this type of fertilizer is very long (a few years) and can be used only in a mixture with other nutrients in quantities of a few percent, and after long maturation process. If manure from poultry mixed with large quantities of plant material (straw mat, straw, sawdust, grass, etc.), calcium carbonate (limestone powder) or slaked lime, is should be left to ferment long enough with regular moisturizing and this mixture It can be used as an additive for food of worms. However, experimentation with this kind of fertilizer should be carried out very carefully because they can cause great damage in the cultivation of worms.

Manure from sheep and goats is a high-quality material to feed the worms and to obtain an excellent humus. With added calcium carbonate and shorter boiling (to "cool down") and wet, the worms eat very quickly and processed in the best humus.

Versatile waste as food for worms

Cardboard and paper are used as food and due to their composition, mainly the cellulose fibers with the addition of mineral charges and adhesives. Especially good is the corrugated cardboard, which is used to make boxes for packing various products. This material is widely accessible, especially in large shopping centers. Most of the boxes end on landfills, while only a small part is collected and recycled in factories for recycling paper. Throwing the cardboard box on the junkyards is a great material loss and environmental damage, because it is beneficial organic material which could be used as food for worms. Special cardboard boxes for transport eggs are consist of very porous pepper pulp which is an excellent material for processing into compost, and the worms over a short period processes them.

The cardboard is an excellent material for preparing the ground for the bed of the worms, and thermal - insulating material during winter time. Some people use it as roofing material for bedding because it reduces the loss of moisture, provides penetration of light and thermal protection in winter.

Food waste, vegetables and fruits (except waste of meat) is also a good material to feed the worms. Some even have very beneficial effect on the process of reproduction. It is important to be crushed in small pieces that quickly ferment and their large surface allow worms to use juices produced during fermentation in bed. Practice has shown that waste such as peels potatoes, raw or cooked (even old, rotten potatoes) is an excellent food for worms. If this waste is of acidic character, you need to add calcium carbonate to achieve a neutral reaction.

Dry deciduous leaves (except oak and walnut) are a good supplement for feeding the worms. They are particularly suitable as a cover during the winter. During breakdown and formation of humus, leaves produce acidic compounds, so you should add calcium carbonate. It is known that compost arising from the perennial leaves decomposition is a high quality material greenhouse production. For these purposes compost is prepared having leaves into piles to which added slaked lime had been added and occasionally been turned over a period of 2-3 years. Compost is ready when leaves structures disappear. Matured compost is mostly mineralized organic matter, so losses of nutritional components are quite large. With proper processing, the worms finish this process in 4-6 months thus having much smaller loss of beneficial ingredients.

Garden compost that occurs with aging waste from the garden (but without the parts of plants that are intensively sprayed with insecticides or other toxic agents) can provide much benefit if used as food for worms. They eat it and enriched it with biologically active substances.

Pomace from distillation of alcohol (from grapes or fruit) with prior preparation, i.e. partly composted with addition of ground limestone or lime is an excellent material for feeding worms and provide valuable humus.

City waste after mechanical separation of metal, glass and plastic also undergoes a process of fermentation and then it is given as food to the worms. Humus obtained this way has a humus-like quality of sewage sludge. Can be used in forestry, horticulture and partly in agriculture, which depends primarily on the result of chemical analysis of the final product.

The ash from the trees that households use for heating is available in massive scale, and is valuable material for the preparation of humus. During burning process all organic matter disappears, only minerals from the trees remain in partially soluble form. After the reaction, the ash is very alkaline due to its content of oxides in water which give alkaline reaction (sometimes in the past these materials were an important raw material for getting soaps and washing clothes - they were totally environmentally friendly detergents).

Preparation of various organic materials for worms feed

As previously stated, various organic (primarily cellulose, vegetable) waste can partly with composting to be turned into acceptable form for the worms. It applies to materials which in original form have too high acidity or structure that is very stable and does not break down so easily (eg. pomace, paste pressed olive oil, straw, paper and cardboard, etc.).

The process is very simple and does not require much work, time and space, depending on the quantity processed. It is important to cut the time needed for partial decomposition of the material and to be drive the chemical and biochemical processes in the desired progress: the formation of glucose and intermediates that can serve as food for microorganisms and worms who do the humus turning process. Hence, the pH must be as close to neutral value of 7.0 which is acceptable for the worms.

The procedure is as follows:

1. The material we want to compost (after cutting as small as possible), is shaken well to a layer thickness of about 20-25 cm on a clean surface (can be left directly on the ground, but then put part of the soil in the humus)

2. Powder the layer with about 2 kg hydrated lime powder per m2. After transfer which is performed by mixing the components, it is humidified by adding of about 20 liters of water, in which there is dissolved 0.5 kg urea, and then compressed. The humidification could be done with liquid fertilizer (liquid part of manure containing urine from cattle) instead of a solution of urea.
3. Over this pressed layer a new another one layer is placed with a thickness of about 25 cm which powdered again and poured with the same amount of urea and lime as before. After the humidification with 20 liters of water this layer is compressed too.

Figure 5. Lumbriculture of red earthworm Lumbricus rubellus (photo Mihajlov, Lj., 2017)

Repeat until you reach the height of the layer of 80 cm or more. When you reach the desired height, the resulting pile can be covered with foil that prevents fast drying and cooling. Very quickly, usually after 3-4 days the decomposition process begins intensively and pile heats up to 80°C. Maintain enough humidity by occasionally watering the pile with water.

Definition of bed and its formation

Generally, commercially produced in bed means the amount of humus, semi processed foods and novel food which occupies approximately 2 m2 area with a height of 25-30 cm, rarely 40 cm (some larger producers' beds built to a height of 60 cm which reduces the number operations to extract humus) with a volume of 500 -1200 Liters and contains about 100,000 to 120,000 adults and young starlets and worms that live individuals. The volume of good bed for sale should have a volume of 200 Liters (4 bags of 50 liters filled with upper layer of the bed). Bags for transport must be permeable to oxygen, especially when temperatures are higher.

The beds can theoretically be formed with several start-up worms, but with the previously mentioned level of fertility should not take too long to get to optimal population level for the worms have cost production. Therefore, the basic amount of worms to form the bed buy from strong breeders to contain at least a half of the amount of units. In this way in just for 3 months you can have at least one real bed already for the next 3 months will make a total of 4 beds.

How to make a bed?

Generally, the bed should be prepared on angled terrain (to provide leakage of excess water from precipitation). Acceptable slope is of 1-2%. The terrain is repaired and cleaned from logs, plants debris and stones. Then measure the space for individual beds, taking into account, in the case of a large number of beds to leave enough space between them because of labor necessities that must take place during the production of humus.

(A)

(B)

Figure 6. A) Preparation of the bed, B) View of the standard beds

It is very convenient to have a concreted surface (thin layer of concrete is sufficient because it is assumed that you will not have to support large weight), or base of concrete slabs for building spaces by placing 2-3 coats of concrete blocks without the use of mortar binding.

Rainwater drain from the bed can easily be solved by setting up channels with a slope of 1-2%. The only negative point to this method of cultivation is permanent destruction of natural space with concrete.

Surface settlement of worms should be prepared at least ten days in advance and in layers:

– The first layer of hard surface has a thickness of 5-8 cm, and consists of hay, straw, cardboard or any other similar cellulosic material. This layer has the task of allowing leakage drainage of excess water and provides the necessary supply of oxygen to the substrate.

– The other layer has a thickness of 10-15 cm comprising relatively of fresh horse manure or beef fermented (stable) fertilizer, having neutral reaction (pH 6.8 - 7.2). Make sure during the preparation of the layer of compost, it should be added 1 kg lime powder (ground limestone = calcite = animal chalk = ground marble = calcium carbonate) per cubic meter of the material because it is necessary to neutralize the acid. To the worms it serves as a means of digestion. The smaller limestone, a smaller amount is required and there is greater efficiency. Make sure there is no mercury lime (calcium oxide) in bed with worms or slaked lime (calcium hydroxide) as it is of alkaline nature and will kill worms and Cocoons.

After formation of the layers, the substrate is daily moistened with clean water until it does not flow slightly yellowish liquid and until completely ground it lost odor of ammonia, sulfur hydrogen (smell of rotten eggs) or the like.

During all these working operations avoid compacting the surface, no matter if it is by trampling or otherwise – falling down of the substrate must be natural, by the weight of the material, to ensure access of air necessary for the process boiling and later for the life of worms.

The humidity of the substrate at the time of settlement of the worms must be such that the upper layer, when pressed by hand to be able to squeeze a few drops of water, not to be too saturated with water.

Before the settlement, check the acidity (pH) in the middle layer of the substrate. The acidity must be as close to 7.

After introduction of the worms into the bed, the substrateneed good watering in order to achieve optimal humidity.

The worms from the bag are released on the surface of the substrate and are distributed in a layer thickness of 5 -10 cm on the surface of the substrate. Then immediately cover with “geotextile” ‘to reduce the effect of light and cause drying of the material and worms. In the settlement of worms in bed with piles of new material, should remain intact until the first feeding of worms.

One bed should be roughly allocated on 4 m2 for the timeframe of 3 months to achieve propagation of worms so that they can form at least two beds.

Greater dilution of worms is not rational because it leads to slower proliferation. Special procedures achieve greater degrees of breeding. Do not mix the substrate and the new material but leave the worms themselves move into the substrate.

The first feeding should take place after 15 days with a thin layer (5-10 cm) of crushed and good manure (it is necessary to keep a diary of work activities which will include all operations and procedures of the bed which is especially important in factory production humus).

Feeding repeats on every 7-10 days as thin layer. Thick layer of food can lead to poisoning and heating the bed and loss of worms. It should keep in mind that the worms can processed foods depending on their densities.

The best effect of breeding worms outdoors can be expected in May and June when daily average temperatures are optimal. In this need and other factors that affect the speed of reproduction to be optimum, at a temperature of 15 -20 °C, the pH should be 7 and humidity in the bed is 80%. Any deviation from these values more or less reduces the productivity of worms in taking the starlets, and thus playing the new beds. These data are very important if the worms are grown for sale or production of worm worms as protein fodder.

Sharing beds

Sharing beds is performed when the bed is optimally populated, as was previously stated. Usually it happens after 3 months with intensive feeding (not taking into account the winter months), if you started with a half real bed. Before the division of the bed into two or more new beds, it is necessary to prepare the space and ground for new beds (it is done before the intention to separate the bed, according to previously described procedure). Feeding the bed which is divided adjusted so that the last portion of food is given two days before the administration, and decreases vlazhenjeto before the last feeding. Then the food is mostly wet. Thus almost all the worms retreat towards the surface of the bed.

Sharing is done in a way that is lifted layer of semi processed and fresh food to a depth of 15 cm and transfer to other beds. In each new bed is placed on half of that table containing adult and young worms and starlets. The depth of the intake can be determined by observing because you have to remove the top layer of the bed until ready humus layer, identified by homogeneity, brown color and population with worms. In any case transfer should be done quickly to stop feeding the worms in humus. Upon completion of the transfer of worms is removed the finished compost until the bottom of the bed.

Empty bed is preparing for a new settlement in the manner already explained above. The described procedure is also used in factory production of worms and compost on the market, i.e. when ”it is never quite” from worms and humus.

With limited production, subject to only a few beds, or just one, it is only to reduce the number of worms in the bed when you achieve optimal settlement, although there are natural factors that limit or prevent overcrowding in bed.

Undesirable visitors in beds

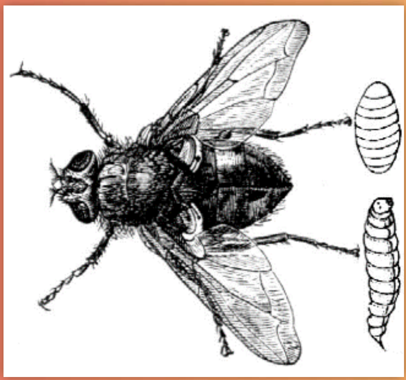
The material from which worms feed often attracts other animals. Worms themselves are food for larger animals, moles, mice, birds and poultry. With these animals is simply to cope with the pest control, fencing and roofing, as previously mentioned.

There are many small insects in beds that are usually not harmful, especially if the bed is in good condition, well fed and monitored. The most frequent visitors found in bed with worms are: ants, larvae of insects, larvae of many species of flies, earthworms and other various soil insects and arthropods.

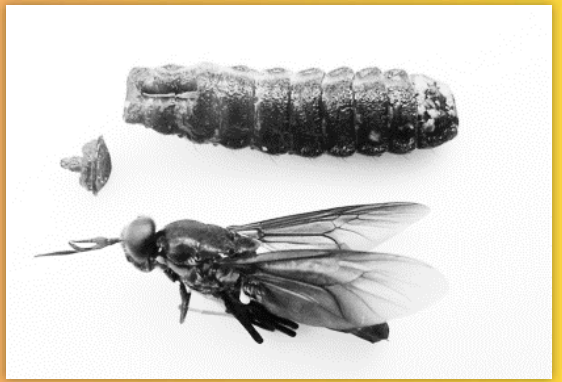
Ants will appear in the bed if it is not too wet and if near their anthill is. Rarely, larger species, such as forest or black ants red ants. In normal production bed ants pose no threat because they are in small numbers towards the bedside table and worms in it, and often "stealing " a bit of food for worms;

Larvae of insects occur in the warmer parts and can be sized up to 4 cm and a diameter of 1 cm, which depends on the type of insect that has laid eggs. Most common are the larvae of the species Cetonia, Nosorosca, Hrusta etc. They pose no threat to the worms, except that eat of worms' feed. Despite their size they are not even significant producer of humus. They are harmful in the free nature because they attack the roots, and in bed for only a source of propagation of this species;

The larvae of many species of flies (mostly house flies) occur occasionally in bed when there is enough food for them and not harmful to the bed. Quite common is the larva of a fly military, black soldier fly (*Hermetia illucens* L.), of which some reach up to 2 cm long and 0.5 cm wide. Some feed (especially if it contains protein components) attract ordinary house flies (*Musca domestica* L.).



(A)



(B)

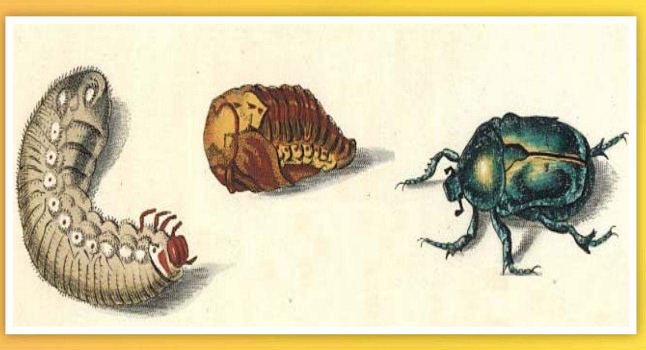
Figure 7. Foreign visitors in bed. A) Ordinary house flies (*Musca domestica* L.), B) Black soldier fly (*Hermetia illucens* L.)

Soil worms from the genus Enchytraeus are small, up to 10 mm long, white worms. May occur in a number (up to 250.000 units/m2). They feed from the simplest decomposition products of the organic material and mineral colloids. They multiply, bread and decompose in bed. They are considered very useful in the process of humus producing process. The best food for young aquarium fish and can achieve a high market price.

Type of locusts from subclass Collembola, belonging to subtype Hexapoda, are small, up to 2 mm in length, white small animals, like termites, which when disturbed jump to 10 cm in distance. They feed on the remains of plants and mushrooms, and appear in profusion in well water beds with worms in bed when conditions are ideal. Well come in bed because they are not harmful.

(a)

(b)



(c)

Figure 8. Foreign visitors in bed. A) Soil worms from the genus Enchytraeus, B) Locusts from subclass Collembola, C) Cetonia aurata

“Eco-Box”

Eco-box is a wooden or plastic box with a small volume (enough if the bottom of the box has dimensions 35 x 45 cm and a height that is 30 cm), with a permeable bottom and allows for leakage of excess water and air circulation. No matter for the type of the box it should be coated on the inside with plastic mesh with openings 2 mm perforated plate or foil with the same holes. Geotextiles gave excellent results as it prevents the worms to escape from the box and protects from entering the undesirable visitors such are mice, birds, frogs etc. The box plated with mesh, at the bottom a layer of crushed cardboard with a thickness of 2-3 cm is laid, and on it a layer of 5-6 cm purchased humus from worms mixed with cardboard. Then, after a few days while watering and adding small amounts of calcium carbonate, settle previously purchased or otherwise procured worms.

Populated box is put on the sown area of the balcony, courtyard or garden and can be placed in the basement or in the apartment. Restrictions are only possible because of leek of excess water as the box usually does not have unpleasant smell. By using the most appropriate substrate and carefully wetting, the water problem is easily solvable. Immediately after the settlement starts with feeding. As food for the worms are decomposed cardboard and paper, pieces of stale bread, pasta, all kinds of waste from fruit and vegetables, old decayed cotton towels, a clump of black coffee and tea, food scraps, milk and whey. Adding small amounts of calcium carbonate powder or slaked lime is required. If lime is to be used adding should be performed carefully and before placing the waste in the bed, because in direct contact with the worm it will kill them.

Measuring bed’s pH

Most of life’s most important processes take place in a neutral environment or its approximate value of pH. It applies to all plant and animal life. Exceptions are rare. Only the digestive composition meet extreme values of pH.

In chemical laboratories pH is measured by electronic instruments called pH-meters.

However, there are portable pH-meter designed for field work. Often they run on batteries and are less accurate than laboratory (but still sufficiently accurate and reliable). They are delivered with specially designed electrodes that are best suited for certain materials to be tested.

The latest portable pH-meters are with a miniature construction, some do not even need a battery to operate and the price is affordable. Some may measure the humidity and the media which put measurement. It is very convenient to measure soil and humus.

In practice, for fast and satisfactory results on determination of the pH, indicator strips are use, or so-called pH-paper (often simpler understanding called litmus paper).

Measurement performed by detaching the part of the indicator, who's strip is placed on moist compost or humus and left in contact (it takes 5-10 seconds). Under the influence of the chemical reaction the bar changes color. The tape is then compared with the scale shades of colors that are located on the box cover. The color, most similar to the tape that used for measuring determines the value of pH.

Number of worms in bed

When assessing the value of the bed, or the determination of most appropriate time for dividing the bed, it is necessary to determine how many worms at that point are in the bed. It can nearly be determined "by eye". Counting the worms in the whole bed would be a huge loss of time and it would not be because good due to the possibility of disturbing the worms.

Figure 9. Counting of worms in the bed

One of the most accurate methods for estimating of the number of worms are done based on the counting of the sample that is removed from the bed by means of a specific but simple tools. It is made of metal in the form of a rectangular tube. The dimensions of this tool is so suited to be a volume of 1 liter. The lower edges of the sheet metal must be sharp in order to enable rapid penetration into bed. When one wants to assess the number of worms in bed without disturbing the bed, the described tools, quickly bores the bed. The penetration should be deep enough so the entire tool can be filled with content from the bed i.e. to raise 1 liter of material.

Figure 10. Using of pots with a fixed volume to determine the number of worms in bed

Because worms usually do not linger in larger numbers in the lower layer of the bed, especially if there is a significant layer of finished compost, it is necessary to perform a vertical cross-section of the bed with a shovel to measure the thickness of the layer partially processed and fresh foods, in which there is about 90% of all worms in the bed.

The following example explains how to perform the calculation described based on assumed data for a random bed:

Sampled 1 liter counting found:
Adult worms---------80 units
Young worms------------30 units
Total -------------------110 live worms
Cocoons-------------------15 units

2. By measuring the cross-section of the bed the following information is obtained:
Layer thickness populated ---------- (18 cm)
Thick layer of humus------------(8 cm)

3. If the surface dimensions of the bed are:
Length ---------(2 m)
Width ----------(1 m) And then the calculation for the whole bed:

Number of adult worms:	80 x 18 x 2 x 10 = 28 800 units
Number of young worms:	30 x 18 x 2 x 10 = 10 800 units
Total of worms:	28,800 + 10,800 = 39 600 units

Now add another 10% of the worms in the humus, then the bed is:
39 600 + 3 960 = 43 560 worms.

From here we are free to conclude that the bed is populated with half the optimal number of worms that should be represented in the bed.

USE OF HUMUS

Humus and the fertilizers

It is well known that in addition to the soil in small quantities the humus alone does not ensure sufficient quantities of the following elements: nitrogen, phosphorus and potassium necessary for intensive growth of plants. These macronutrients are essential in the construction of cells in the synthesis of amino acids that build up protein molecules participate in the transmission of energy and nutrients etc. photosynthesis.

The lack of any of these macronutrients leading to discontinuation of intensive growth and reduced yield.

Fertile soils contain macronutrients in sufficient quantities for normal and natural plant growth. With a long and intensive cultivation of plants cultivated land is exhausted. Usually the lack of nitrogen and potassium in the soil is detected. Not only these elements are used as food for plants, they are easily drained after rain and compaction are lost in deeper soil layers or in river flows.

Phosphorus in nature for the most part is bound to insoluble minerals, difficult to pass the surface layer of soil. When added to the soil through fertilizers that partially binswith the soil strucutres it bedomes insoluable, hense difficult to lose.

Another group of chemical elements, also necessary for normal development of plant organisms are needed in much smaller quantities. It is only enough to have them in traces in soil, to play their role in the development of plants. Because of these low concentrations, these elements are called micronutrients. This group of trace elements include zinc, manganese, molybdenum, copper, iron, boron, and some others. In addition, there is a constant need for something greater amounts of calcium and sodium. Concentrations of all these minerals in the water that comes into contact with the root system of plants (thus forming soluble compounds) must not pass a certain value. Higher concentrations affect on the roots and on the plants poisonous and corrosive. So it needs to use amounts of chemical additives at dosages prescribed by the manufacturer, or as recommended by the expert institutions that perform analysis of the soil.

In humus derived from worms and macro and trace elements are generally found in biologicaly most appropriate form, in complex compounds but at very low concentrations, away from toxic concentrations.

The humus obtained from the worms is material rich in beneficial bacteria and fungi. From this point of view it is a true biological bomb: soon after its application, depleted soils begins to live intensely, abruptly began to multiply beneficial microorganisms necessary for soil fertility, especially if the soil has organic material.

Humus and sowing

Just before the sowing, the surface of the field is covered with a single pour of humus produced by worms in an amount of 1-10 liters per m2. This corresponds to a layer of 1-10 mm. The added humus varies by type of crop, the general condition of the soil, the remaining funds to increase fertility (manure, peat, compost, residue from the previous crop, etc.) and of course the available quantities of humus in the soil, in accordance to a chemical analysis of the soil.

Applied humus, which must to be wet because only so is the best, needs immediately to be shallowly incorporated into the soil and possibly after the sowing is watered. This simple procedure (including watering) ensures the greatest advantage of the beneficial effect of humus as bio activator. Young plants, seedlings, after permeation with its roots come into contact with biological active and fertile environment and are well developed.

Experience proves the general belief that the areas applied with humus from worm has fewer weeds. Simple, humus somehow reduces the ability to seed germination of weeds. At the same time, this is not the case with the seeds of cultivated plants. At the cultivated plants often is noticed more intensive germination and development in the first developmental stage. Cotyledons usually ate larger and used to develop earlier than the first true leaves.

Humus' use in planting vegetables

Unlike the application of humus in field crops, the planting of the seedlings in vegetables does not requirethe entire surface of the field to be covered, but placed in holes for planting. So the material is economically consumed, and the effects are improved. Again it should be emphasized that there must not be allowed to dry humus into the holes but to place the plant seedlings immediately, so that the whole root system to be in touch with humus.

Very good results are achieved if the seedlings before planting are stick in a bowl of water in which there is small amount of worms' humus, so it is good the root to be soaked and covered with a layer of humus. After proper deployment of root and plant the hole should be filled with soil and waterThis is suitable for planting of smaller quantities of seedlings of fruit and vegetables, as for larger number of seedlings it would be a major loss of time.

In growing seedlings of vegetables by using containers, humus is added to the substrate for sowing and soakng in dissolved humus would not make sense.

In general, vegetable seedlings are burried a bit deeper than it grew in the nursery, some vegetables are buried up to the cotyledons (first leaves emerging from the seed) or up to the real first leaves.

Seedlings will not display effects of shock and the success is guaranteed if procedures are implemented as described above and if the seedlings were sufficiently fresh and transplanting to avoid the hot afternoon sun.

Here is some data about certain common types of vegetables:

Tomato: enough is to put in the whole 0.1 - 0.3 liters of humus, to lay roots and buried with soil. A bed to bury under the first leaves: the buried part of the stalk will emerge further buildup of the root that will help alleviate food plant in full race. Immediately after planting should be thoroughly watered.

The next adding of humus is after harvesting the first fruits, with humus shallowly buried around the roots of plants during cultivation. According to literature, the amount of vitamin C is increased up to 100%. Plants showing greater resistance to diseases and more developed root system. Such action has an impact and content of biological active calcium humus.

Pepper: for this “pampered” plant and for its development needs a lot of favorable conditions: well-composted soil, rich soil with nitrogen and potassium, with a neutral reaction, a lot of moisture and heat, it is when rasaduva in jamichkata to to put 0.1 - 0.5 liters of humus. The rest of the procedure is same as with the tomato.

If you are planting varieties or hybrids of peppers that have a high potential for yields and larger fruit (such as California wonder or giallo quarto, as well as some domestic varieties) it is required during development of plants to add humus and fertilizers also. These is the only way to achieve a high quality production. With the use of humus the high percentage of vitamin C, can be increased up to 100%. It also improves the appearance and aroma of the pepper fruits.

Some varieties of short pepperoni (chili peppers), using humus of worms with proper care during the winter months is achieved perennial flowering and fruit bearing at the same stalk if grown in a protected space. The application of worm humus in growing pepper increases the number of leaves, flowers and more branching of the crown.

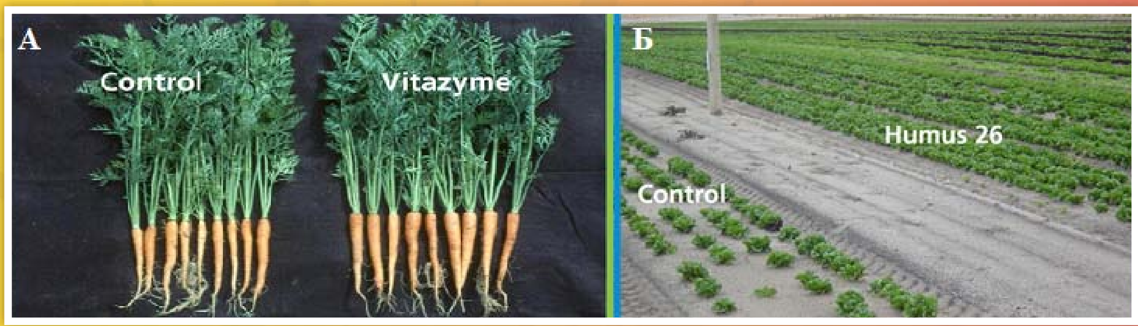
Cabbage, because this plant (and related to it: broccoli, etc.) has a strong and long root system, it is the root to surround with humus using around 0.1 - 0.5 liters of part humus mixed with soil in which to grow roots.

Eggplant: has very favorable reaction to the use of worm humus, giving a number of large fruit, and whole plant is stronger and more resistant to disease. In transplanting the eggplant, the holes are filled with 0.2 - 0.5 liters of humus.

Pumpkins, cucumbers, watermelons and melons, although these crops are usually sown in predetermined growing place, adding right amounts of humus enables earlier flowering and harvesting, especially if the seedlings are grown in pots with peat or containers filled with humus from worms. While the dimensions of the containers with peat should not be larger than 6 x 6 x 6 cm, because humus ensures enough food for development of the first few leaves and a strong root system.

Sowing can be done indoors much earlier than in the open, and considering that and ready prepared 'nests' with seedlings are passed along, so it comes to damage to the root of these cultures are more sensitive.

The root during its development pushes through the soil's layers and is normally spread in the environment.



(a) (b)

Figure 11. Using of humus in the vegetable production A) Carrot, B) Salad (Organic farming systems)

Carrot, parsley, celery: although for these crops do not recommend using manure, only using of fertilizers is recommended, worm humus can be used safely both before sowing and feeding as well.

Harvested vegetables have improved taste and odor, and in the literature were mentioned the increase in the amount of vitamin C in carrots up to 500%, and the similar increase should be expected at terms of beta carotene.

Potatoes grown in humus of worm contains up to 200% more vitamin C, and the whole plant is lush and more resistant to disease. If in the preparation of humus dolomite powder or dolomite lime is used, due to increased concentration of magnesium yields will be even greater because it is known that this is a key element in the production of potatoes.

Similar positive results show all other types of vegetables that are grown in soil enriched with humus from worms. Improvements are detected already in use and very small amounts of humus. Larger amounts of humus will not yield the expected greater increase in quality and quantity. Because humus is relatively expensive, so it should not exaggerate with taking large quantities. In this case the increased costs for soil fertilization may diminish the resulting benefit from fertilization.

The amount of humus which would constitute 30% of the soil mixture or substrate, is used only in greenhouse production and cultivation of exotic plants. And in such case there is a need to use the highest quality and fully mature humus.

Particular field of use humus very rich mixture in the production of 'health food', in which should be avoided completely using any fertilizers and accessories. In that case all the needs for nutrients, including those macronutrients (NPK) plants adopt the humus. It should be emphasized that these quantities are limited and often inaccessible to some plants and therefore rapidly deplete the humus.

Usually it is considered that rational and most effective is to use humus to 10% in the surface layer of soil. In agricultiral literature, there is a division of soils to the contents of humus in their structure:

Contents of humus:
Up to 1% - very poor organic matter content
1-3% - moderate organic matter content
3-5% - good organic matter content
5-10% - excellent organic matter content

Litich soil:
Particles larger than 2 cm
Particles of 0.2-2 cm (gravel)
Small particals soil:
Particles of 0.2-0.25 mm (coarse sand)
Particles of 0.25-0.02 mm (sand)
Particles of 0.02-0.002 mm (clay powder)
Particles of 0.002 mm (colloidal clay)

This display shows that presence of already 5% of humus makes the soil fertile for the crops that are demanding in terms of nutrients.

Replanting of fruit trees and vines

Each fruit seedling during planting is subjected to shock-damage to the root system, and even the change of the substrate itself is a shock. Therefore, the transplantation is carried out in the phase of biological dormancy, late autumn or early spring. Then all metabolic processes are minimized.

If possible, transplanting should take place in the fall, after the cessation of vegetation because the plant is preparing to launch a new spring vegetation!

Fall planting of fruit trees, vines, and other perennial plants is particularly important in areas where there are early warm temperatures and droughts. During the autumn and mild winter, when rains are frequent enough, the root has enough time to adjust and stvoranje the basic formation of new roots.

Reduced root system, deliberately cut after removing from the bed in the nursery or farm, requires a suitable environment in which at least would be susceptible to outbreaks of major damage. It is a known procedure of soaking the roots of the seedling before planting in fresh manure from cows for more successful rooting. This procedure is justified because of several reasons: the fresh manure does not contain pathogenic bacteria and fungi that would scuttle the root, and is also rich in nutrients for plants in suitable concentration, there is biological acceptable acidity and ultimately, contains small amounts of phytohormones, growth factors that occur in the digestive tract of animals. They accelerate callus formation in the damaged areas and develop a new root system.

Humus from worms in its characteristics has the same effect as the root and the fresh feces of cows. Furthermore, it contains some useful components in larger concentrations and does not contain components which assist to the development of bacteria and fungi. These components are used in the metabolism of the worms, hense the reduced possibility of developing root diseases.

The added humus is the ideal substrate for the initial root development and will feed the plant even next year. Adding fertilizers should be adjusted and soil moisture. Soil with higher moisture content or soil with more frequent rainfall or irrigation, allows adding more humus without risk of damage to the roots.

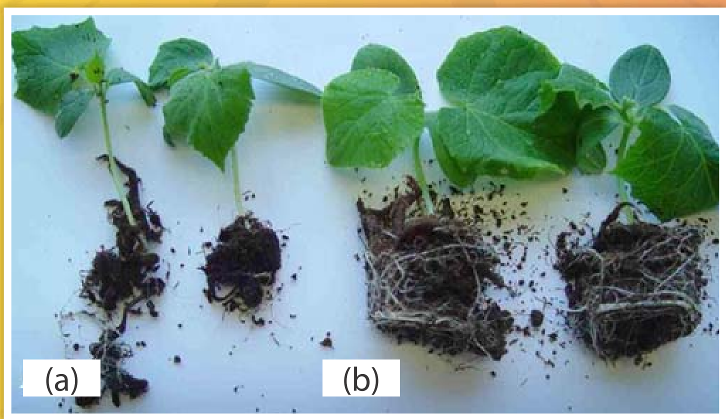


Figure 12. Development of the root system A) Control without humus B) The use of humus

The method of preparation of worms' humus at the time of planting of vines is the same as the fruit and can only be used mixed with small amounts of humus. Quantities containing of 3-5% give good results.

Humus from worms can be used for later enrichment and activation of soil of the orchards and vineyards. To that end humus is shallow burried in the soil in that area as far as the width of the crown of fruit trees or rows of vines. The depth of humus deposition must be such that it should as close as possible to the roots in moist soil layers.

In the application of humus in orchards and vineyards very useful is mulching of the soil with weeds, straw, chaff, and another cellulose material, which in wet conditions bacteria and fungi from the humus will rapidly turn into a new fresh humus. Mulching, simultaneously slows down the loss of moisture from the soil, and improves the soil heating. Fruit and grapes grown on mulched orchards have better quality (in viletarurata: increase the content of vitamin C in apples and pears to 6 times!). Also, the stems are stronger and more resistant to drought and disease.

Application of humus in floriculture

After all that was said before about the properties and uses of humus, it is probably needless to talk about the expected positive effects of its use in floriculture. So here are only the most basic data on the types of use.

The intensive cultivation of flowers, such as chrysanthems, carnations and gerbers, due to the rapid exhaustion of the soil, needs constant fertilizing and activation of soil.

High quality compost from worms require less space and manipulation as is lighter, has a more suitable structure to use, has great ability for biological regeneration of soil “salinization” after continued use of fertilizers. With regard to this feature the humus is irreplaceable, so it’s no wonder that the Netherlands imports large amounts of humus from worms.

Flowers grown in pots are typical consumers of the finest soil mixtures that enable long-flowering and nice-looking plants. And in this case worms’ humus used assupplement in an amount of 3-15% gives very good results. Apart the activating and nutritional action, the humuost acts as a buffer, which corrects the acidity of peat added. The various species of palms, kali, ferns, and many other plants grow magnificently by using humus from worms. The proportion of humus in the mixture of flowers should not be more than 5-10%.

Roses give a positive response to fertilization with humus from worms. The whole shrubs intensively develop and provide multiple buds. Composting is performed similarly to fruit trees and vines: the humus is deposited near the root. Such fertilization roses easily tolerate in times of drought and cold, and during an attack of fungal diseases.

Cactuses can also be grown with the addition of humus, versus the general, quite oposite opinion. The author used the humus for many years as an addition to the substrate, even in sowing in an amount of 2-5%. Certainly, for this purpose only high quality, fully grown humus should be used.

Figure 13. Use of Bioredworm lumbrihumus in horticulture (Bioredworm, 2016)

Convenient way to use the humus is by watering the flowers with humus extract. This prevents entry of excess amounts of organic raw materials in the substrate, and is achieved with beneficial effect to the root development.

Use of humus with cactuses give good results if used in the spring and the first half of summer. When temperatures are high and growth is intense. So by the colder days come eith the autumn the most part of the humus is spent.

Using the extract of worms' humus

If fresh, moist humus is dipped in water, some of the nutrients are transformed into the solution. This solution can be used for feeding the plant through leaves by using the sprayers (foliar fertilization).

In order to prepare a compost extract, humus 0.1-0.2 liters per liter of water should be used. Humus should remain submerged overnight. The remaining can be used as fertilizer and usually has a great value.

For foliar fertilization the extract derived from humus is diluted with 10 parts of water.

The extract can be enriched with certain amount of soluble fertilizers (allowed for use in organic) to increase the concentration of nutrients and the solution, thus obtained, is used for irrigation. This solution of humic components sometimes called "humus water" or "humus tea." Excellent effects are obtained in the application of area under vegetables which is applied by foliar fertilization or watering. Used as foliar fertilizer acts as a preservative for many plant diseases and insect repellent.

Table 2. Use of Lumbrihumus (Pejic and Martic, 2013)

CULTURE	PLANTING/ TRANSPLANTING	NUTRITION
Tomato	0.2 – 0.3 L LH per root	With tilling 0.3 – 0.4 L LH around the plant
Pepper	0.1 – 0.5 L LH per root	With tilling 0.3 – 0.4 L LH around the plant
Cabbage, brussels, broccoli	0.1 – 0.5 L LH per root	Foliar in a ratio 1:10
Eggplant	0.2 – 0.5 L LH per root	With tilling 0.3 – 0.4 L LH around the plant or Foliar in a ratio 1:10
Beans, peas	0.2 – 0.3 L LH per root	Foliar in a ratio 1:10
Potato	0.2 – 0.3 L LH around tubers	Foliar in a ratio 1:10
Cucumber, squash	0.3 – 0.4 L LH per root	Foliar in a ratio 1:10
Lettuce	1 - 3 L LH after planting m^2	Foliar in a ratio 1:10
Swiss chard, spinach	4 - 5 L LH after planting m^2	Foliar in a ratio 1:10
Beet	4 - 5 L LH after planting m^2	Foliar in a ratio 1:10
Carrot, parsley, celery	4 - 5 L LH after planting m^2	Foliar in a ratio 1:10
Strawberry	0.3 – 0.5 L LH per root	Foliar in a ratio 1:10
Fruits	1 - 5 L LH around root	With tilling 1 – 4 L LH under crown
Flowers	0.1 L LH per liter soil	Mix 5% of the volume of the pot (container) or foliar in a ratio 1:10
Spice plants	0.1 L LH per liter soil	Mix 5% of the volume of the pot (container) or foliar in a ratio 1:10
Conifers	Add 1/3 LH per 2/3 soil	Mix 10% of the volume of the pot (container) or foliar in a ratio 1:10
Olives	1 - 2 L LH around root	Dig 1-4 L LH per m2 under the tree crown
Grapevine	1 - 2 L LH around root	Dig 1 – 2 L LH in the grapevine
Grasslands	3 - 4 L LH per m^2 soil	2 – 3 L LH on m^2 (2 times a year)
Cereal growing	5000 L LH per ha soil	1000 L LH per ha soil (1-2 times a year)
LH – LUMBRIHUMUS; Foliar 1:10 – 1 liter LH per 10 liters water or 0.1 liter LH per 1 liter water		

Another way is by watering the plants with the mentioned solution (extract) with a greater concentration.

HOW TO RECOGNIZE GOOD HUMUS

When each manufacturer of humus for their goods and for each batch of products would give a complete analysis of the major components, then it should not be difficult to choose a good humus on the market. The market in Western Europe and the United States is controlled by contractual norms for determining the quality under 16 possible classes. A simple illustration of the principle of classification is the example of the value of individual factors for the best and worst product is shown in Table 3.

Table 3. – Classification for humus quality

Quality factors	Good hums	Bad humus
Moisture	57,00%	< 20,00%
pH	7	5
Dry matter content		
Organic matter	> 51%	< 20%
Ash	< 45%	80%
Oxygen (O)	1,90%	< 1,00%
Phosphorus (P)	1,90%	< 1,00%
Potash (K)	1,60%	< 1,00%
Calcium (Ca)	1,60%	< 1,00%
Magnesium (Mg)	0,90%	> 4,00%
Iron (Fe)	1,20%	10,00%
Lead (Pb)	0,00 ppm	> 7,50 ppm
Mercury (Hg)	0,00 ppm	0,015 ppm
Chrome (Cr) како Cr^{3+}	0,00 ppm	10,00 ppm
Cyanide $(CN)^-$	0,00 ppm	> 2,50 ppm
Manganese (Mn)	530 ppm	> 1.000 ppm
Copper (Cu)	150 ppm	> 1.000 ppm
Zinc (Zn)	740 ppm	> 2.500 ppm
Cobalt (Co)	10 ppm	> 50 ppm
Bacteria/g humus	>2000 billion	Only 50 milion

Complete table contains more data for each factor as a way of scoring of each value obtained by the analysis. Namely, each sample from a different humues sample has different values for each element, and a relative value of the sample can be obtained only by collecting all the individual points. So, the best humus would have 95 points, and the worst only 10 points. The class determines the price.

As can be seen, the table quality presents strange relationships. For example, the better humus is the one with higher humidity. And the explanation is very simple: the humidity is required to maintain the life of the population of beneficial bacteria in humus, and humus in sales expressed as the largest volume so humidity is irrelevant to measure quantities. Drying the humus humus is conducted only when there is need for its additional processing.

The quality of humus is basically conditioned by the material given to the worms for processing. As previously stated, almost all organic materials that bacteria and enzymes partially break down the polysaccharides can serve as food for worms, however, the best humus arises from manure from the horse and cattle with high content of straw as a source of cellulose.

Moisture only increases the density of this relatively lightweight material. Ignorance to these factors sometimes lead buyers to think that buying humus with humidity want to fool the customer by purchasing water, which is awfully wrong.

In Macedonia few producers are giving the results of the analysis of the product. The humus market exists or does not.

However, based on some visual tests it is possible to avoid the purchase of bad material:

1. Good & ripe humus is odorless.
2. Does not contenti reminants of straw, wood or similar.
3. Has good structure.
4. It has high humidity.
5. Does not contain metal particles or sand.
6. Do not make hands dirty when rubbed between the palms
7. Immersed in pure water gives a yellow-brown solution, the sludge easily stirs after little pressure with your fingers. In sludge or water surface no larger solid residue.
8. Longer standing in wet conditions does not produce mold on it.

These few guidelines can help in the selection of humus for the successful cultivation of plants.

Chemical analysis of good humus presents mainly the following results (deviations in the values of the main components can be 50% up or down, depending on the material production):

Table 4. Orientation results of chemical analysis of humus

pH in 10 % of water eluate	7.40
pH (1:2 vol.)	7.35
E.C. mS/cm (1:2 vol.)	0.75
% H_2O	61.00
% dry matter (105°C)	39.00
% on heated sample (550°C)	47.84
% N in wet (natural) sample	0.84
% N in dry matter	2.20
% N in other forms (550°C)	2.09
% N as NH_3	0.11
% P_2O_5 in total dry matter	1.12
% K_2O total in dry matter	1.87

The comparison made in the literature showing elevated values of the main components compared with the the results of our analysis of the manure and humus samples (Table 5):

Table 5. Average composition of manure and humus

Component	Manure	Humus
Nitrogen (N)	App. 0,5%	App. 2,00%
Phosphorus (P) (as P_2O_5)	App. 0,25%	App. 1,5%
Potash (K)	App. 0,6%	App. 1,2%
Organic matter	App. 20%	> 40%

It is obvious that the concentration of nitrogen is increased up to 4 times. It is a consequence of the creation of large amounts of microorganisms that contain mostly protein mass.

The data in Table 5 shows that the concentration of nitrogen is greater and up to 4 times in the humus than the value of concentration at manure. It is a consequence of creating large amounts of microorganisms that contain mostly protein mass. Composting with worms is relatively easy to perform and control. In terms of conventional composting, it is necessary only to make beds for the material and worms that will be isolated from the soil. The beds occupy a relatively small space, do not create an unpleasant odor, can be moved and can be placed where it best suits. Lumbri humus is richer in nutrients than ordinary compost.

Earthworms (*Lumbricus rebellus* and *Eisensia foetida*) as the main decomposing's of organic matter possess a great potential for rapidly multiplication and are unable to decompose a large amount of organic waste.

After three months from placing the material, ready lumber humus will be obtained. This type of composting would be a good choice for composting of manure in situations of lack of space. This principle is particularly useful for processing of waste from kitchens, because worms quickly consumed substances, solving a problems with the occurrence of unpleasant odor. Composting with worms do not cause high temperatures to destroy pathogens and seeds of harmful weeds. For these reasons, this method is more suitable for composting food, paper, scrap yard and garden.

If you have sufficient quantities lumbri humus, you do not need another fertilizer. Primarily the humus seen increase the content of organic matter in the soil. Nutrients from the humus gradually moves into the soil, where is ensured a constant supply of nutrition for plants.

Lumbri humus can be used for organic production, for producing seedlings, for indoor plants, for the recovery of contaminated environment as well. Humus is capable of preventing the growth of weeds, and is also effective means against the occurrence of methyl *Cuscuta epithymum* L.

The most important question that asks each manufacturer refers to the benefits of composting.

What will I get if I compost?

If you compost you would get very, very much, in the present, and even more in the future. In fact, all of us would receive benefit, whether composted or not, or whether we have the conditions to do so. Benefit of composting have producers, consumers of crops, and also producer which use lumbrihumus. With composting we will not irreversible lose the organic matter, but rather it will bring back again to nature.

Agricultural producers ccould receive an additional income that ccould be obtained from the producing of lumbrihumus. Incomes from the lumbrihumus production, which has better quality and quantity, will increase continuously. In addition, farmers ccould save incomes for buying fertilizer, by making and using of own lumbrihumus.

Humus as a market product

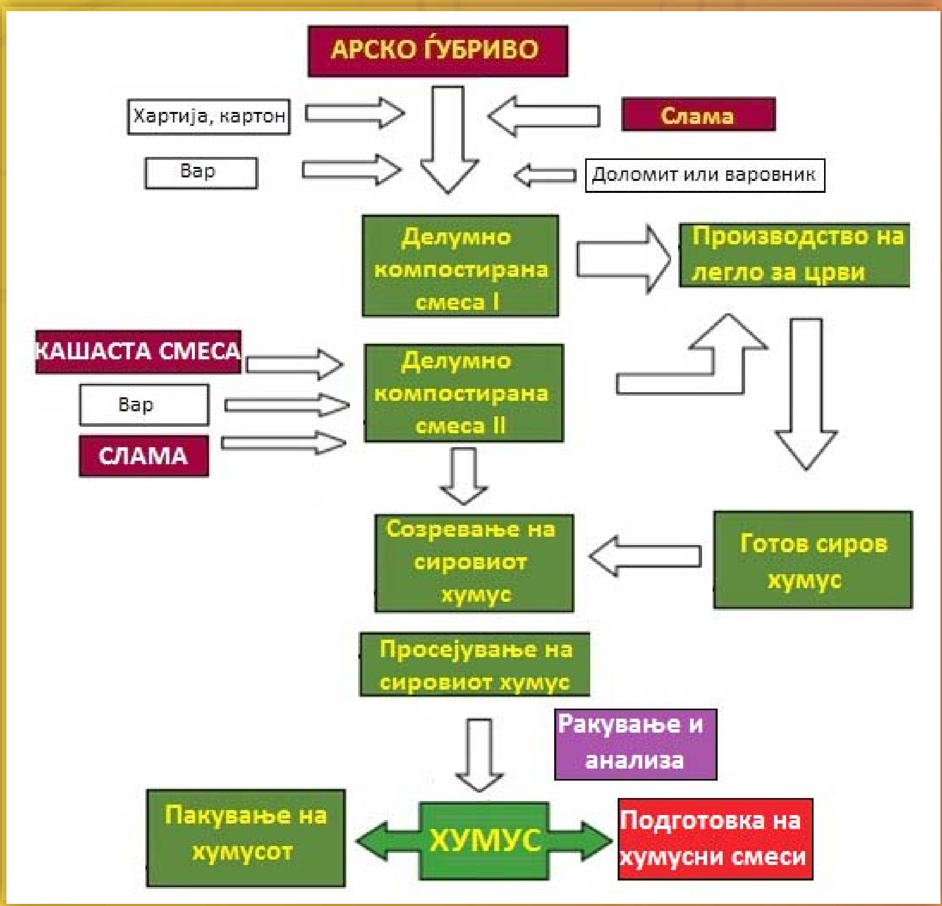
Humus obtained from earthworms is very valuable material, except that it is used in pure form for processing soil, many is used for preparation of humus - soil mixtures that are used as substrates for growing flowers, picking orchards, transplant flowers and vegetables in seedling production, for growing forest species and similar uses of plant production. A number of consumers of these humus blends is growing, both in households and among in professional breeders of plants, and continually increase the number of new manufacturers.

Some manufacturers worryes that the market is saturated, and there will be no one to produce humus. There is no fear of that opinion! Problems with market plasman will have those farmers who will not try to sell humus wich is not enough quality and farmers who avoid professional product control. Farmers who once uses quality humus and will see the positive results of humus uses, will become a permanent consumer of humus!

The market will recognize the real, honest and trusted manufacturers! Some European countries have adopted legal procedures for preservation of humus in the soil and also obligation for enrichment the soil with higher humus quantities.

The real producer of worm humus acts as an adviser to the users of the product. Simply, it is impossible to work these job without professional training: read the available literature on soil and growing plants, attend the professional meetings in which at least listen the experiences of other users of lubrihumus, record their results and experiences in run own diary to avoid errors in the work. The production of humus for the market have not to end like selling raw humus bulk or in large quantities (wholesale). To achieve greater financial benefits needed several operations:

1. Maturation by drying to humidity up to 50% which is carried out in a period of 1-3 months with occasional turning the layer deep to 50 cm and a cover in case of rain. It is ideal to have roof space that protects from the sun. Humus must never dry out under 40% humidity. During this procedure humus is saturated with oxygen and completes the process of humification. Achievement a suitable content of moisture is necessary for further processing procedures.
2. Sieving of hand or slope sieves. For larger quantities should be used vibrating sieves with a simple structure that allows sowing more cubic meters per hour. The holes of the sieve should be no larger than 5 x 5 mm.



Scheme 1. Technological procedures in the production of compost from california red worms (Dugonjić, 2007).

It is practical to have several frames with a sieve with holes of 3-6 mm, which could be quickly and easily changed as needed for the sowing of various materials. Thus can be seated and many other ingredients in the preparation of planting mixtures for various purposes.

In general, the manufacturing process flowc according to the chart 1 which is shown below. The chart shows two alternatives of production: first, the processing of manure as a feedstock which adds other materials if any, and the second alternative which use straw and slurry. The second technology is used in wet automatic cleaning of stables at the large farms.

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NATIONAL AGENCY FOR EUROPEAN EDUCATIONAL PROGRAMMES AND MOBILITY

Supported by ERASMUS +

Project No. 2015-1-MK01-KA202-002855
Developing OER and Blended Modules for Agriculture and Rural Development, Erasmus+ KA202 Project