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GUIDELINES
FOR SOIL SAMPLING FROM AGRICULTURAL FIELDS

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Content

1. INTRODUCTION

1.1 What is soil?

A Russian scientist Dokuchaev introduced the first scientific definition for soil, based on genetic principle i.e. how the soil was formed, in 1886. He considered the soil as a natural-historic body i.e. Earth's top layer, naturally altered under the influence of the water, air and various dead and living organisms, weather and the relief over the geological substrate.

For the farmer, the soil is the natural environment on which they grow their crops.

No matter different soil types can differ strongly among themselves, they all have certain common characteristics:

- The soil is a three-phase system composed by four main components: solid phase (minerals and organic particles), liquid phase (water and soluble matters in it) and gas phase (soil air).
- The soil is a product of the external environment. The factors that determine the soil establishment and the changes are named as soil formation (pedogenic) factors. These are: geological substrate, climate, organisms, terrain, time and the human factor. They can become combined in their influence thus to produce various soil types. Agricultural soils are under strong changes under human influence, and this is named as anthropogenization.
- The soil is natural body, characterized by own internal and external aspect i.e. morphology. The soil in its depth has differentiated horizontal zones i.e. genetic horizons. All genetic horizons in a soil compose its soil profile.
- The soil is dynamic and evolutionary system since there are permanent physical, chemical, and biological process. Under their influence the soil is under permanent change and in longer period the soil is characterized with brand new character, changes, evolves from one to another soil type, from one to another development stadium.
- The soil is tri-dimensional body situated between the lithosphere and atmosphere.
- The soil is a medium on which cultivated and natural plants grow. It is an environment in which root system develops and holds the upper part of plant. It provides the plant with nutrients, water and oxygen.
- The soil is a natural heritage (resource) of great significance for the human society. It plays great role and many of its needs. Food production for the humans and the animals grows on soil, fiber, various forest products and energy providing materials. The soil provides raw materials for the food, chemical and textile industries, provides us with medicinal herbs and protects us from floods. Humans live on it and from it: builds buildings, digs foundations, installations, irrigation and draining channels, roads.

1.2 What is soil fertility?

Soil fertility is a complex function which more or less makes the soil substrate capable of growing plants and differentiate potential and effective soil fertility. The first is defined by the constellation of all the factors of the soil and the second one by the intensity of all values of the vegetation and soil factors.

To obtain yield, the most important factor is the effective soil fertility and it needs to improve if we want to achieve our main goal - increasing the yield of cultivated plants.

In addition, soil fertility is divided into several categories: primary, natural, traditional and technological fertility.

The primary fertility is accumulated in soils from the nature, developed under natural vegetation. Their main parameters are the content of humus and nutrients. If these soils are to be used for crop production, they are also referred to as “virgin soils”.

Natural fertility occurs after the exhaustion of the primary fertility. It is the result of a pedological property of the soil. It is characterized by the absolute depth, soil texture, profile structure and natural drainage. Soils that are longer under exploitation, their natural fertility is a key indicator of the ability of the soil as a substrate for growing plants.

The traditional fertility reflects the influence of the soil anthropogenization over long period of time. In fact, it is a fertility climax of the soil occurred by the application of different cultivation techniques such are manure fertilization, shallow tilling and legumes cultivation.

The technological fertility relies on natural fertility, or anthropogenic soils suitable for growing plants are created from unfertile substrates. The technological fertility is a result of radical, contemporary mechanical actions including hydro-technical meliorations, and supplemented by efficient mineral fertilizers and other techniques. The technological fertility is one of the characterizations of the modern plant production.

1.3 Which nutrients the plants extract from the soil?

The nutrients which plants need for their growth and development are classified in two groups: mineral and organic (Figure 1).

Plants absorb minerals in their mineral form and they mainly originating from the soil. Those are inorganic ions, salts or molecules. In this group are also the mineral forms of nitrogen (nitrate ion - NO_3^- and ammonia ion - NH_4^+), regardless they originate from organic compounds which under microbial decomposition and mineralization of organic matter are transferred into mineral forms.

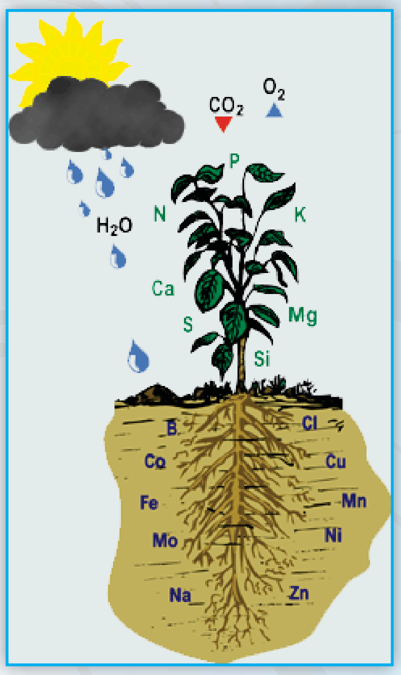


Figure 1. Nutrients uptake by the plants.

Using numerous scientific experiments, it is confirmed that 17 chemical elements are essential for the life of higher plants. For such reason, they are named as necessary, essential or biogenic elements, which, then, are divided in macro and microelements. Beside the necessary elements, plants, also, can absorb beneficial and harmful (toxic) elements (Figure 2).

- *Macroelements (macrobiogenic elements, macronutrients)* – these are present in the plant composition in larger quantity (> 0,01%), hence to which plants need them in larger amounts. The following elements are classified in this group: carbon (C), oxygen (O), hydrogen (H), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S);
- *Microelements (microbiogenic elements, micronutrients)* – these are present in the plants in much smaller quantity as compared to the macroelements (from 0,001% to 0,000001%), hence to which the plants need them in smaller quantities. The following elements are in this group: iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chorine (Ni) and nickel (Ni);
- *Beneficial elements* – are not necessary for growth and development of plants, but if they are available they have positive and simulative effect over the plants. The following elements are in this group: cobalt (Co), sodium (Na), silicon (Si), aluminum (Al), selenium (Se), vanadium (V), titanium (Ti), lanthanum (La), caesium (Cs), and
- *Toxic elements* are the following: chromium (Cr), cadmium (Cd), uranium (U), mercury (Hg), lead (Pb), arsenic (As) etc.

The macro- and micro- prefixes should be understood only as a necessary amount of certain element, but no as their role in plants life, since each one of the mentioned 17 elements is essential for plants life. In the group of macroelements are often separated organogenic (non-minerals) elements which compose more than 90% of the live matter. In the classification of organogenic elements, N, P and S are usually omitted, regardless that they are mandatory constituents of organic matter, but in significantly smaller quantities as compared to the quantities of C, O and H, and plants absorb these elements in mineral form.

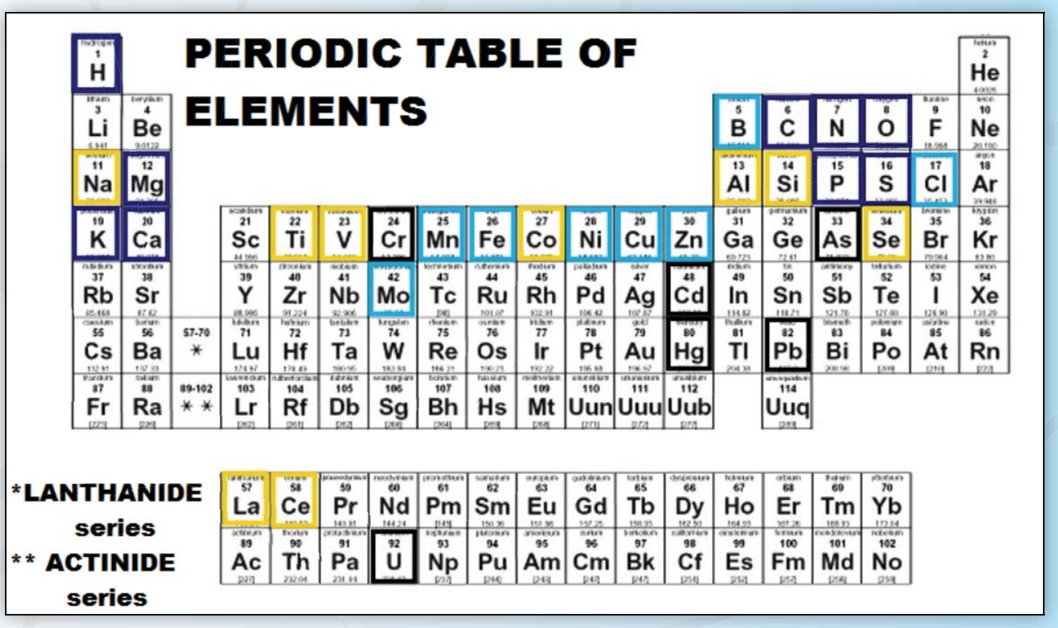


Figure 2. Division of macroelements (dark blue), microelements (light blue), beneficial elements (yellow) and toxic elements (black) in the periodic table of elements.

Beneficial or useful elements, when plants are in optimum growing conditions, do not have physiological role. As growing conditions are becoming unfavorable their influence is more favorable, even more, in certain conditions they can partially and only non-specifically replace the function of necessary elements. The remaining elements are useless or toxic, in relation to their influence on growth and development of plants. Improvement of research methods gives possibility for assessment of physiological functions of some useless and even toxic elements.

2. Basic principles of plant nutrition

Fertilization is one of the most important factors for achieving high and qualitative yield. This can be achieved only by designing suitable plant nutrition; which will lead to the utmost achievement of variety genetic potential, and through this to the achievement of maximum yield with responding quality. In plant production, adequate plant nutrition often achieved with fertilization, can present 30-70% of all the factors, which influence the production process. Nevertheless, to apply certain measures for increasing the yield and the quality using fertilizer, we need to know the crop requirements for nutrients, total nutrient content in the soil and their quantity which is available for the plants. Based on these parameters, suitable and reasonable dosages of fertilizers are recommended for application, which, on one hand contribute to achievement of high and good quality yield, and on the other hand are environmental friendly i.e. soil, water and air.

Application of organic fertilizers i.e. manure, mulching, composting etc. shall be integral part of fertilization, especially in the stage of planting orchards and vineyards. An input of organic fertilizer might significantly contribute to long term improvement of soil fertility in correspondence to its physical and chemical characteristics.

It is necessary to have satisfactory level of available macro and microelements in the soil for normal growth and development of plants. For clarification, in Table 1 is presented the level of nutrients in the soil and the level of necessity for phosphorus and potassium fertilization.

Prior to the application of additional nutrients into soil, it is necessary to perform agri-chemical soil analysis and through which we will determine the content of nutrient elements in the soil of specific agricultural field. Applying the amounts of nutrients larger than necessary for a given crop, not only unnecessarily increases the cost of production, but can lead to reduced yield and yield quality, toxicity and blocking of the assimilation process of other nutrient elements, thereby their lack for plants.

Table 1. Nutrient elements level in the soil and necessity for fertilization with phosphorus and potassium.

Level label	Level evaluation	Content in soil (mg/100g)		Necessity for fertilizing with P_2O_5	Return of K_2O of the total plant uptake (%)
		P_2O_5	K_2O		
M	Very low (meliorative)	< 5	< 5	Meliorative fertilization (+100-200% more than plant uptake)	100
A	Low (poor)	5-10	5-10	Very high fertilization (+30-50% more than plant uptake)	80-90
B	Middle (medium provided)	10-15	10-15	Moderately increased fertilization (+10-30% more than plant's uptake)	60-70
C	Optimum (good provided)	15-25	15-25	Only maintain fertilizer application (only P quantities up-taken by the plant are returned)	50-60
D	High (over provided)	25-40	25-40	Moderately decreased (returned 20-30% less than plant's uptake)	30-40
E	Very high (extremely provided)	40-50	40-50	No fertilizing necessity (do not apply fertilizer for 1-3 years with control of the micronutrient level)	Do not fertilize for 1-3 years
F	Harmful	> 50	> 50	No need for fertilizer application for long term. Protective anti-toxic activities are applied. Strict control on micronutrients.	To abandon for longer period of time

Deficiency or sufficiency of nutrients usually cause certain symptoms on the plant which indicate that the presence of certain element is insufficient or excessively. In cultivation of field crops, fruits and grapes excessive levels of nutrients is rare and isolated, while in production of vegetables in greenhouse and plastic tunnels lately, there are many examples of fertilizers overuse, that result with corresponding symptomatology and have negative impact on the quantity and quality of the yield.

If we are familiar with typical symptoms of deficiency or excess presence of nutrients, a visual inspection is enough to identify disorders in terms of their absence or presence (Figure 3). Unfortunately, it is often difficult to give an accurate and proper diagnosis because the classic symptoms of symptoms of deficiency or sufficiency of some elements are very similar with each another or they are similarities with symptoms of some diseases. Making the diagnosis is additionally complicated if there are more signs of lack of several nutrients on the plant. The biggest problem in identification of nutrient deficiency or sufficiency based is that these symptoms indicate that the problem already exist and generally it is observed through reduced plant growth, lower yield and/or poorer yield quality.

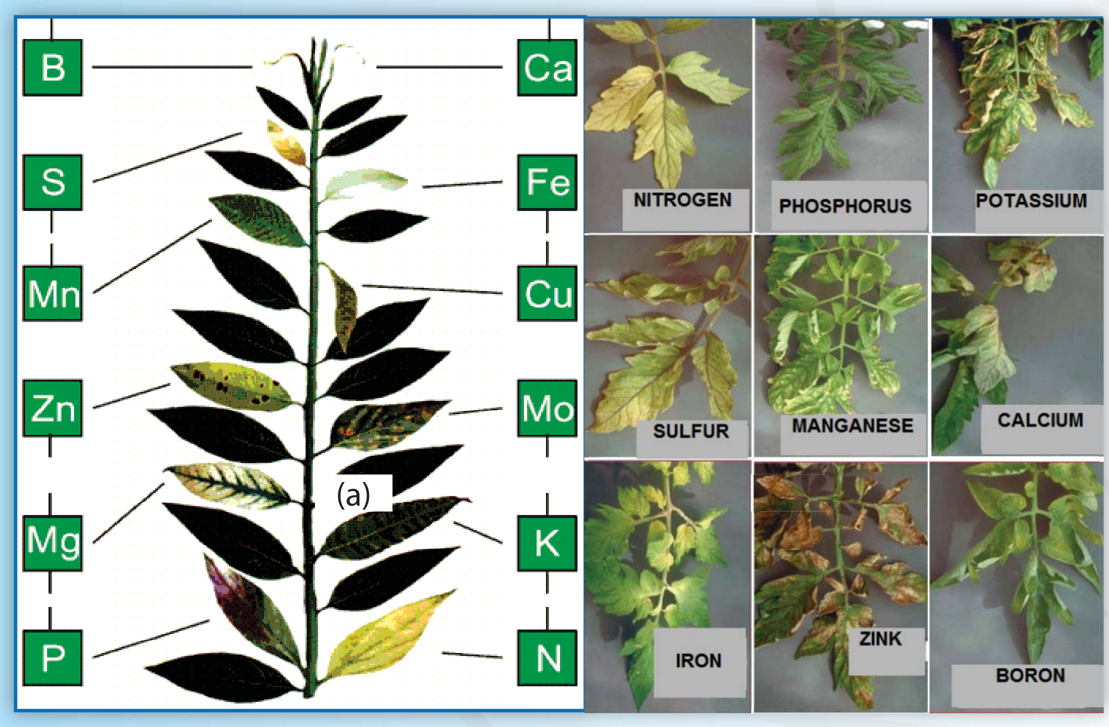


Figure 3.
a) Visual nutrient deficiency symptoms on leaf,
b) Symptoms of deficiency of macroelements and microelements on tomato leaf.

The general deficiency symptoms of most essential nutrient elements in plant nutrition, (carbon, oxygen and hydrogen excluded) are given in Table 2.

Nutrient deficiency symptoms described in Table 2, can significantly vary in different plant species from above described ones. The described symptoms are general and point to the most frequent deficiency symptoms.

If there is doubt on deficiency or sufficiency of nutrients in plant crops based on visual check, for precise determination of the nutrient status, it is necessary to perform soil analysis of the field where the crop is cultivated. Sometimes, more accurate identification must be made and analysis of plant tissue from the culture to determine the exact cause of the symptoms of the crop.

Table 2. General deficiency symptoms of most essential nutrient elements.

Nitrogen (N)	Reduced apical growth (the top of the plant and the root); upward growth is spindly; leaves in early development stages are pale yellow and green; later they become yellow and in certain cases even orange or red; the deficiency is firstly visible on the lower leaves while the chlorosis spreads from top to bottom of the leaf.
Phosphorus (P)	Reduced apical growth (the top of the plant and the root); upward growth is spindly; leaves in early development stages are blue-green, sometimes with darker green color as compared to the leaves with higher content of phosphorus; in later stadiums leaves are becoming dark green, sometimes having brown on the edges; leaves fall off earlier, starting with older leaves.
Potassium (K)	The top of the leaf becomes brownish; some plants tend to develop brown or bright spots on the leaf, usually more in number at the edges of the leaves; the deficiency is firstly usually visible with the lower leaves.
Calcium (Ca)	Symptoms are usually associated with younger leaves; they are twisted, the top is rolled backwards, edges rolled towards the lower side; leaf edges can be with irregular shape and with brown spots.
Magnesium (Mg)	In earlier developmental stages of leaf there is manifestation of chlorosis between leaf nerves, separated with green parts which creates round stripe-effect; the symptoms are firstly visible on the lower leaf side.
Sulphur (S)	Young leaves have pale shade of yellow and green, similar to appearance of the nitrogen deficiency; shoots growth is slightly reduced.
Zink (Zn)	The chlorosis between the leaf nervature is accompanied with wilting of the parts with chlorosis; dwarf growth and shortened inter nodal distance.
Manganese (Mn)	Light-yellow to yellow leaves with emphasized leaf nervature; in certain conditions, brown spots appear which later tend to disappear; symptoms can be firstly observed on the colder leaves.
Boron (B)	Has strong influence over plant's growth spots; stems and leaves can be significantly deteriorated; reduced pollination; upper leaves are with yellow-red color and can appear as being burned.
Copper (Cu)	Younger leaves are becoming pale-greenish with slight appearance of chlorosis on the edges of the leaf.
Iron (Fe)	Chlorosis between the nervature of the young leaves.
Molybdenum (Mo)	Leaves are with chlorosis with wrapped or cone-formed edges; molybdenum deficiency often results with nitrogen deficiency.
Chlorine (Cl)	In open field production, there are no deficiency manifested cases.

3. Why do we need soil analysis?

Soil fertility can be controlled through laboratory soil analysis on soil sample or in another words, soil analysis is made in order to determine the soil fertility i.e. its current capacity which has fundamental importance for plant production. With soil analysis, we can determine the level of available nutrients and the level of necessity for their input, we can estimate the yield increase and proper nutrient management for given agricultural field. It is the only way for rational use of mineral fertilizers and organic manures on a scientific base and soil analysis results, in order to achieve high in quantity and quality yields, being economically and environmental friendly.

Soil analysis is beneficial tool for determining the level of the nutrients in a soil sample and for determination of nutrition requests of different crops. Regular collection of soil samples and their testing in laboratory can contribute to trace the changes and the efficiency of the applied nutrition program. Special attention should be given to the fact that the laboratory results are as exact as technique applied for proper soil sampling and notes for each sample taken are good.

If farmers properly and regularly take soil samples and make laboratory soil analyses, they will have multiple benefit: on-time and proper crop fertilization which contributes to the achievement of higher yields and improved product quality. Application of recommended fertilizer quantities in certain time periods decrease the pollution of soil and ground waters with excess fertilizers which are applied on agricultural land.

Soil analysis is performed on soil sample. In order to obtain real and accurate results for the status of physical and chemical parameters of the soil, the soil sample should be properly taken depending of the culture and the field where it is taken, properly packaged and brought for testing in the laboratory. For the purposes of laboratory, soil samples from fields can be taken by authorized laboratory personnel or soil samples can be delivered by the clients themselves.

4. Which are the most important parameters the soil analysis needs to consider?

Laboratory parameters commonly tested with a basic agri-chemical soil analysis are pH value, electrical conductivity (EC), total nitrogen, available phosphorus, available potassium and organic matter (humus). All the parameters are tested on previously laboratory pretreated soil sample.

4.1 pH value of soil sample

pH is a unit which expresses the level of acidity or alkaline reaction of the soil. Measurement of the pH level is made with pH-meter. Soil acidification can be a caused by industrial pollutants, especially acid rains in the extensive areas of bigger energy factories, but the cause might be also some natural processes.

The process of acidification causes a series of problems in the process of plant nutrition, since in the acidic soils, mineral colloid fraction is subject to long-term leaching by water-soluble acids in the soil and then gradually revolving into clay acids, which are easily mobilized into deeper soil layers.

pH reaction of soil directly influences the plants through toxicity from increased concentrations of H^+ or OH^- ions or indirectly through changing a whole series of soils agri-chemical characteristics. Indirect pH influence can be monitored via the changes over the availability of biogenic elements or via microbial activity change in the soil.

Different plant species do not tolerate the effects of acid soil reaction in the same manner. Opposite of acidity, most of the plants have poor tolerance to increased alkaline level of soil, typical for arid (dry) climate.

4.2 EC value of soil sample

The concentration of the total amount of soluble salts in the water is usually determined by measuring the electric conductivity (EC). High concentration of dissolved salts in the soil relates to soil salinity, it is measured in soil (with consistency of a paste) and when the EC value is ≤ 4 miliSiemens/cm ($mS \cdot cm^{-1}$), the soil is considered as salty.

Increasing the levels of salt and alkaline reaction of soil can be due to the application of excessive amounts of mineral fertilizers or by irrigation with water with high salt content i.e. waste water of different origin. Therefore, irrigation leads to high soil productivity, but on the other hand can lead to soil salinization due to high content of soluble salts or lack of drainage system. Soil salinization (alkalization) increases the level of Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}.

Factors that lead to development of soil alkaline reaction are:

- Aridity (lack of rainfall);
- Surplus of primary chlorides and calcium sulfates;
- Salt depositions (sea, underground salinization);
- Irrigation with water containing soluble salts.

Saline soils are characterized by:

– High pH value,
– Bicarbonate toxicity (with reduction of the level of Ca^{2+} и Mg^{2+}),
– Unfavorable sodium influence,
– Low availability of microelements (possible toxicity with Se and Mo),
– O_2 deficit (anaerobic condition), due to poor structure.

“Fixing” salty soils can be performed with “excessive” irrigation with water containing low levels of soluble salts and good draining system. “Fixing“ salty sodium soils can be performed by leaching of soluble salts and adding gypsum.

4.3 Total nitrogen content

Nitrogen has special place in the group of necessary elements. Originates from the atmosphere (N_2), but is taken in mineral form, therefore is considered as a part of mineral elements. It is a part of the proteins, nucleic acids, photosynthetic pigments, amines and amides and other compounds that are the basis of life, hence the chemistry of this element is the most important part of plant nutrition. Nitrogen significance is even greater since quite few organisms can use it directly from the atmosphere (78,1%) in gas status (N_2). Large amounts of energy are needed for transferring molecular forms of nitrogen into ammonia and nitrates (946 KJ = 226 Cal). On the other hand, nitrogen is easy to be transferred back in molecular status, in which is most stable, thus is easy released from the soil.

Nitrogen in the soil can be found in organic and inorganic compounds. Inorganic nitrogen is in the nitrate forms (NO_3^-) and ammonia compounds (NH_4^+). Nitrogen in soil is mostly found in depth from 0-20 cm, in insignificant quantities 3 – 8 ppm NH_4^+ and 3 – 10 ppm NO_3^-. The largest nitrogen quantities are 3000 – 4000 kg/ha and they are mainly attached in the organic matter. Yet, part of the soil nitrogen is fixed in ammonia ions in the clay minerals and organic matter.

Organic part of the nitrogen is found in the humus and partially decomposed plant and animal remaining.

Organic pat of the nitrogen is represented by humus and partly decomposed plant and animal remains.

Nitrogen content in soil mostly depends of the humus content having in average 5%, and in dry areas up to 10% nitrogen.

Nitrogen in soil can be found in the following forms:

- As ammonia or nitrate compounds, but only 1-2% of the total nitrogen;
- In organic compounds, which are easily decomposed providing material capable for nitrification (amino acids and amides);
- In organic compounds which are slowly decomposed by soil microorganisms.

4.4 Content of available phosphorus

The purpose of determination of available phosphorus in soil is to evaluate soil reserves of this essential element for plant nutrition, based on which one can estimate the necessary quantities of phosphorus fertilizers.

Phosphorus is non-metal which in nature, soil and plants appears in a five-valent form. It is a part of significant organic compounds i.e. nucleoproteins, phospholipids, enzimes etc. Phosphorus cycle begins with decomposition of phosphoric compounds in the soil, their absorption by the plants and again creation of minerals in the soil. There are 170 minerals containing phosphorus, scattered on all magma rocks.

Phosphorus in the soil can be found in organic and mineral phosphorus. The content of organic form depends on the content of organic matters in the soil. About 50% of the organic phosphorus is in a form of phytins, nucelin acids (DNA and RNA) and lecithin. The phytin originates from the plant seeds, but partialy it is created through soil microbial activity. The phytin compounds with Ca, Mg and Al are hardly soluble. Organic phosphorus appears in the soil from manure and green manure, compost, forest layers, root residuals, died microorganisms, insects and animals that reside in the soil. This phosphorus turns into available for the plants after decomposition i.e. after the mineralization of the organic matter.

The transition of phosphoric compounds in the soil are under biological influence of the plants and microorganisms alongside the colloidal and chemical processes. The direction and character of this process depends from the pH reaction, carbonates content and other factors.

Plants play certain role in mobilization of the phosphorus compounds in the soil. Some crops are good in use of hardly soluble phosphates (phosphorite and apatite) because they acidify the soil solution by releasing plenty H-ions from their root, i.e. different acids. Some of these crops are lupine, peas, while cereal crops have difficulties in using these hardly soluble phosphorus forms.

Phosphorus fertilizers are better used if deposited near the root zone (in rows), rather than scattered over all the field. It is so due to the ability of the root to absorb the phosphorus only from the soil that is in direct contact with it.

In the decomposition process of the mineral phosphates the biggest role is on the microorganisms which excrete organic acids. These processes in the soil are influenced by mineral acids produced by various microbial processes, as by the application of various acidic fertilizers (KCl, $(NH_4)_2SO_4$).

Organic phosphorus can also be decomposed through microbial processes. The phosphorus transformation from humus is more severe and those phosphorus forms are less available to the plants, as compared to the forms originating from cattle and green manure and plant debris.

4.5 Content of available potassium

Determination of available potassium in the soil helps to identify the presence of this element, necessary for proper plant nutrition. The required quantities of potassium fertilizers will be determined on the based on its content in soil.

Potassium is alkaline metal quite spread in nature. In soil and in plants it is identified as one-valent cation (K^+) with reduction characteristics. It is not included in organic matters, but it is loosely bond mainly to the proteins. Potassium has a role of a specific activator i.e. modulator of enzyme activity.

In soil, potassium originates from rocks and minerals that are basic material for its formation. Part of the potassium from the rocks and the minerals remains in the soil in heavy soluble form, and it is in accessible form for the plants only in minor quantities.

In arable field, in a depth of 0-20 cm total available potassium can be found in quantities from 1-2% i.e. 30.000-60.000 kg/ha K_2O. Sandy and peat soils have less potassium content.

The potassium in the crystal structure of minerals is the main potassium source in soil. During decomposition process of minerals and under the influence of various factors, the potassium becomes available to the plants. Such decomposition is performed under the influence of acids, water, temperature and certain bacteria.

Exchangeable potassium is connected to the surface of organic colloids and clay particles. Exchangeable potassium makes less than 1/100 parts of the total potassium, but is still significant potassium source, direct or indirect, for plant nutrition.

The potassium in the soil solution or soluble potassium is found in form of potassium ions (K^+). The soluble potassium is directly available for the plants, but those quantities are not enough for achieving high yields.

In organic matter (humus) there are less than 0,1% of available potassium (K_2O). Crop residues contain certain potassium quantities: cereals 9-15 kg/ha, arable crops 30-48 kg/ha, alfalfa 64 kg/ha, clover 75 kg/ha. For example, if stems of corn and leaves and head of beat are incorporated into the soil, significant amounts of potassium can be returned, hence lesser the need for application of potassium fertilizers.

4.6 Organic matter content

Organic matter in the soil originates from the residues of the living organisms, which are more or less decomposed and then again are building organic matter on the soil.

The organic matter in the soil is:

- source of nutrients for the plants;
- basic structure part of the soil;
- aggregate stability of the soil;
- soil cultivation factor;
- assists in mobility of water and air in the soil;
- assists in water retention;
- prevents erosion;
- has buffer effect (pesticides, nutrients etc.);
- prevents leaching of nutrients from root zone to deeper soil layers;
- gives color to the soil (warm-up).

The amount of organic matter is small as compared to the other parts of the soil, but is of essential soil part due for it:

- determines the difference between soils types;
- influences a lot of physical and chemical characteristics of the soil;
- it is basic source of energy for activity of living organisms and the microorganisms that live in it.

According to the particle size, organic matter in the soil is divided in fraction of large parts, which have maintained their organized structure of living matter and represent inert soil organic reserve, and fraction of humus and humic acid. This part of the organic matter in the soil is very active because of its colloid characteristics, or as we know humus is the product of live matter and its natural source, humus is resource and stabilizer of organic life on Earth.

Soil humus is divided into nutritional and permanent humus. Nutritional humus is composed of easily decomposable carbohydrates (hemicellulose, cellulose, sugar, pectins, starch), organic acids and decomposable proteins. Nutritional humus is excellent food for bacteria and swift source of energy, which they obtain during the mineralization of the organic matter. By product of this process is water, CO_2, N, S and P_2O_5, some inorganic acids, antibiotics, plant stimulators and sticky matters (bio-cement) which strength the structural aggregates of the soil.

Permanent humus is a result of decomposition and re-synthesis in the process of creation of true humus. Permanent humus is stable, difficult to decompose organic complex in the soil. In the process of humification, the organic matter is enriched with carbon, while for soil fertility the most important are humic acids, if originating from soils rich with bases, in a presence of clay colloids, under reduced oxygen level.

Carbon and nitrogen origin in the soil is from the atmosphere, and they are inserted in the soil with assimilative process of the microorganisms and higher plants. The sulfur partially originates from the atmosphere since it can be found in gas as SO_2 and H_2S, while the phosphorus originates solely from some soil material. All this elements are part of humus and in the process of organic matter decompostion, which is done by soil microorganism, they are transformed in mineral forms and become available for plants.

The releasing process of organically tied elements and their transfer into available forms is usually called mineralization or mobilization of nutrients. This relates to all processes that lead to the transformation of unavailable reserve nutrients into available. Talking about humus in that manner, it refers to its decomposition in small molecules of organic compounds that can undergo mineralization process or suitable for direct availability by the plant root. Now it is clear that humus is created through biochemical process, actively participated by various microorganisms (fungi, bacteria, actinomycetes and earthworms as well), depending on the conditions they act in. The most important factors that influence the work of these are soil air and water regime, pH, temperature, the amount and quantity of freshly introduced organic matter in the soil.

In soil of natural biocenosis, the intensity of creation and decomposition of organic matter is balanced which results in stable humus content. Turning the soil into agricultural production tool, decomposition processes are inevitably activated, hence the ability of all soils on which agricultural activity is performed to reduce the content of organic matter. The time for which the organic matter content is reduced depends on the techniques that are applied during production process. Therefore, during implementation of certain agricultural practice it is an imperative to understand the effect it causes over the balance of the organic matter content in the soil. It is necessary to say that under normal agricultural activity reduction of the organic matter content in the soil is relatively slow process.

Crop residues with good biogenic characteristic decompose quite fast, they influence the rise of microbial populations of different microorganisms and soil mesofauna (amplify soil biogenity). One part of partly decomposed fresh organic matter, with assistance of the microorganisms rebuilds humus, process called humification. Many research data prove that nutrients gained from the crop residues have the same nutritional value as the manure.

After the decomposition (catabolism) of freshly applied organic matter in the soil is over, another fascinating transformation (anabolism) starts, assisted by all the living organisms in the humus (humification). In the first stage of decomposition the crucial role is given to fungi; macrofauna and mesofauna (pre-digestive phase) which cut big particles and decompose resistant materials as cellulose, lignin, chitin etc. In case of unfavorable conditions (excessive amount of water, anaerobic conditions) the first decomposers of the fresh organic matter are the bacteria, leading to the production of harmful toxic substances (methane, formaldehyde, hydrogen sulfide, phosphine) which have negative effect on growth and development of plants.

During the first step, the small organic matter fragments and the excrements of macrofauna and mesofauna are favorable medium for the growth of bacteria, algi and nematodes, speeding up its decomposition. The biggest amount of CO_2 is released into the atmosphere and only 20-30% is incorporated in the new humus. From the carbohydrates, less than 20% are transformed into humus as the lignin, tannin and phenol components humify with more than 75%. It is important to emphasize that the nitrogen humifies with coefficient averaging 50%.

After the catabolism of fresh organic matter are finished anabolism follows with synthesis of the "soil plasma". Soil plasma has liquid consistency having proteins, salts, other diluted organic fragments and water. It is in fact, "soil blood", since the water contains different diluted nutrients and suspended smaller particles. Therefore, the soil porous structure plays a role of a blood stream, transporting various plasma components and securing presence of oxygen and water. In such conditions, from the plasma, accompanied by synthetic processes and connection of clay particles, a stable humus matter in soil is created which maintains favorable structure by creation of complexes of organic and mineral compounds i.e. structural aggregates. Hence, the humus is also known as "a dormant force of the soil or sleeping force and foundation of soil natural fertility i.e. source of energy and fertility of Mother Earth".

The humus, as active colloidal and organic fraction of the soil connects with the mineral colloid particles by various ways, hence forming stable complexes of organic matter and minerals which are basis for aggregation of particles in soil into structure aggregates.

Basic groups of humus matters are humic acid, fulvic acid and hunimines.

The content of the organic matter in soil can be increased, reduce or maintain on the same level. The changes are slow since components of the humus, humic and fulvic acid are very resistant to decomposition. The organic matter in soil in average is composed of 50-54% carbon and 4-6% nitrogen, having C/N ratio of approximately 10:1. Tilling is incorporation plant residues with wide C/N ratio, by applying organic matter into the soil we put organic matter with wide range of C/N. The microbial activity gradually narrows this wide ratio through carbon oxidation, using the released chemical energy for its own purposes (chemosynthesis). As long the C/N ration does not drop to certain level, the total released amounts of nitrogen are used by the microorganisms for their own purposes. The release of nitrogen and making it available to the higher plants starts when the C/N ratio is <25:1, while its total assimilation from the microorganisms is when C/N ratio is > 33:1. The nitrogen is temporarily unavailable for plant nutrition when it is incorporate in the microorganisms. Such kind of immobilization is called biological fixation of nitrogen and it lasts until the moment the microorganisms die (i.e. until mineralization of microorganism mass).

C/N ratio depends on the physical and chemical characteristics of the soil, so in acidic soils is it commonly wider than in the neutral or alkaline soils. In the sub-plowing soil layer the C/N ratio is narrower as compared to the soil layers closer to the surface.

5. When to collect soil samples?

Depending on the crop and the purpose, soil samples are most commonly taken in spring or in autumn. Vineyards or orchards soil sampling is best to be performed in spring or just before the vegetation is to start, but the best timing is before primary tillage activities begin.

It is quite common that farmers having specific difficulties with growth and development of the crop to take soil samples during the crop vegetation.

However, best timing to have lab soil analysis is two months before planting or sowing. Still, weather conditions are not always favorable for soil sampling, thus time of few weeks before planting or sowing is period long enough for soil sampling to take place (Figure 4).

Figure 4. Harvested field just before soil sampling in August.
(photo: Vasko Zlatkovski)

6. Basic rules for proper collection of soil samples

There are many ways and tools for soil sampling, more or less different, but all of them have the common principle, and that is the sample must be representative for the area where it is taken from.

While soil sampling it is to be remembered that soil is not uniform and there are remarkable differences between the soil surface and depth of soil profile. More importantly, based on an analysis of few grams to several hundred grams of soil, one makes conclusion for soil quality weighing about 1 t, as weighs a soil layer of depth to 30 cm. Therefore, during soil sampling one shall bear in mind the soil sampling manner because it shall reflect as real picture as possible for the soil condition on entire agricultural field. Agricultural field is a plot which in the past years have been utilized as one unit and on the plot the same culture have been cultivated, same agricultural practices have been applied (cultivation, irrigation, fertilization etc.).

The tools needed for proper sampling must be clean, and as for the types of the tools, those are drill or cylindric auger, shovel, spade, digger (Figure 5; a, b). Beside the soil sampling tool there is need for knife, little shovel, tape meter, plastic bucket, plastic bags for soil collection, paper clips for recording data related to the sample (Figure 6).

(a)

(b)

Figure 5. Tools for soil sampling:
a) different types of auger
б) various types of soil sampling tools

Figure 6. Tools and utensil for soil sampling.

The soil sampling should be performed with the most suitable tool related to the soil specifics (example - if the soil is wet or with stones it is better to use drill or spade instead cylindrical auger). Regardless of the chosen sampling tool, it needs to be clean always, as it is the same for the plastic bucket and the plastic bags.

Increased accuracy of soil analysis can be achieved only by taking larger a larger number of single probes. Places from which individual probes are taken must be distributed properly.

Single probes can be taken by walking in zig-zag line, W or X pattern or randomly, depending on cultivated crop, type and uniformity of field and other factors. In order to choose the most suitable sampling pattern, the person who takes the samples must have good knowledge about the field and cultivation practices which are applied or have been applied on it. This is especially important for perennial crops as orchards or vineyards.

Regardless of the chosen soil sampling model, it is of utmost importance that the final sample should be a representative sample of soil for the sampling area.

Representative sample is usually taken from a plot of a size up to 1 ha, uniform in elevation and soil quality.

If the plot is bigger than 1 ha, has different appearance, differs for color and other characteristics, different cultivation measures and practices are applied, it has slopes or there is higher and lower part – map of the plot is sketched and it is decided which part of the plot will be sampled and how many samples will be taken (Figure 7).

Care should be taken to avoid small, low and wet locations of the as well as parts of the plot close to trees, roads or fences. No need to take Sample near piles of manure or storehouse with fertilizers. No need to take sample when the soil is very wet or immediately after rainfall.

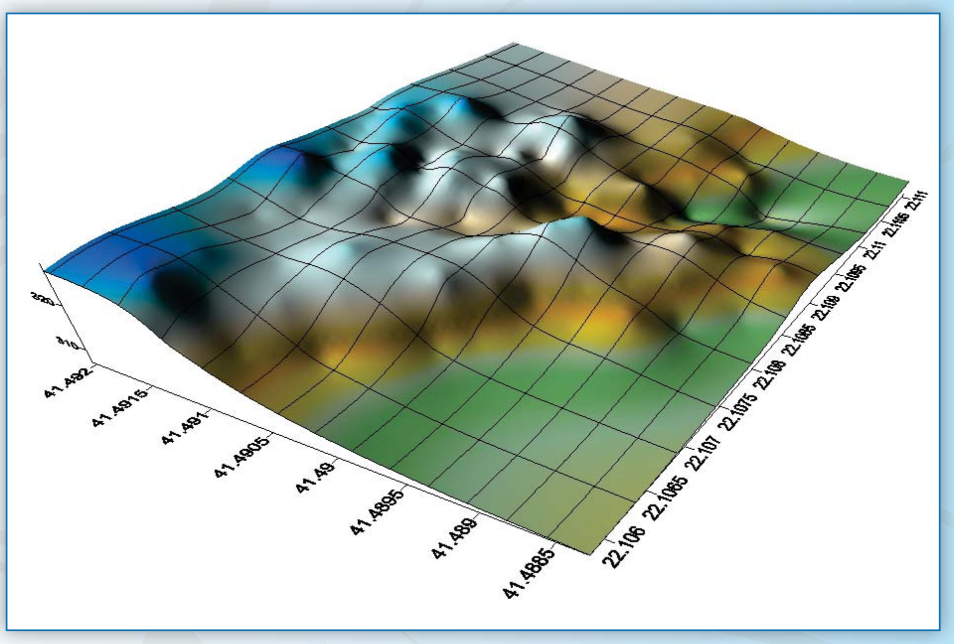
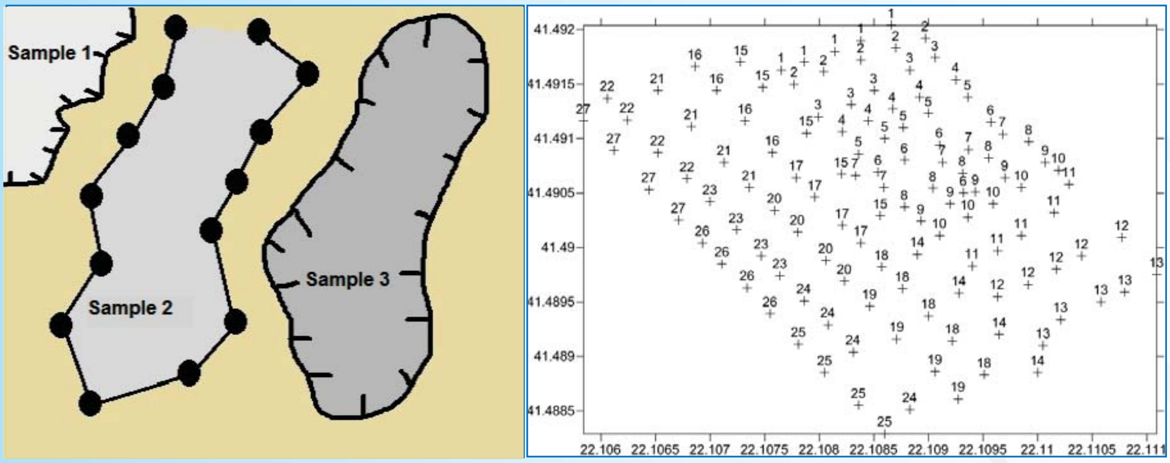


Figure 7. Field from which representative soil samples shall be taken.

Due to its size and terrain difference, there are 123 single probes grouped in 27 representative samples. Each single probe is recorded with its GPS coordinates during sampling procedure (Figure 8, b).

Figure 8 illustrates the zig-zag sampling pattern and preparation of one representative sample from several single probes. The reason for preparation more representative samples from one field might be its terrain diversity (Figure 8, a), or its size and diversity, hence more representative soil samples are prepared (Figure 8, b).

The depth from which samples are taken depends on the plowing depth and cultivated crop. Usual soil sampling depth for field crops and vegetable crops is 0-30 cm. For orchards and vineyards, soil samples are taken from one spot but in two depths: 0-30 cm and 30-60 cm.



(a) (b)

Figure 8. Soil sampling from field with different characteristics.

a) The samples shall be taken from plots or part of plots which are uniform and they can be considered as one unit. In case of visible differences in soil color or texture, in zig-zag pattern movement several single probes are taken and they are grouped in **three representative samples**.

b) If the plot is very big, bigger number of representative samples are taken (1 ha = 1 representative sample). Each dot (number on the map) is one single probe. The single probes with same number are grouped in one representative samples which is taken to the laboratory for soil analysis. Each dot (number) on the map is a GPS coordinate, from which each single probe is taken.

7. Soil sampling from arable land

Walking in zig-zag over the arable land, depending on field size, 10-20 single probes are taken (Figure 9). The single probes are taken from 0-30 cm of soil depth i.e. in soil plowing depth and they are grouped in one representative soil sample (Figure 10). The representative soil sample is composed of the soil taken with single probes from different parts of the field which is subject to soil testing. Representative soil sample is the sample which is taken for analysis in the lab.

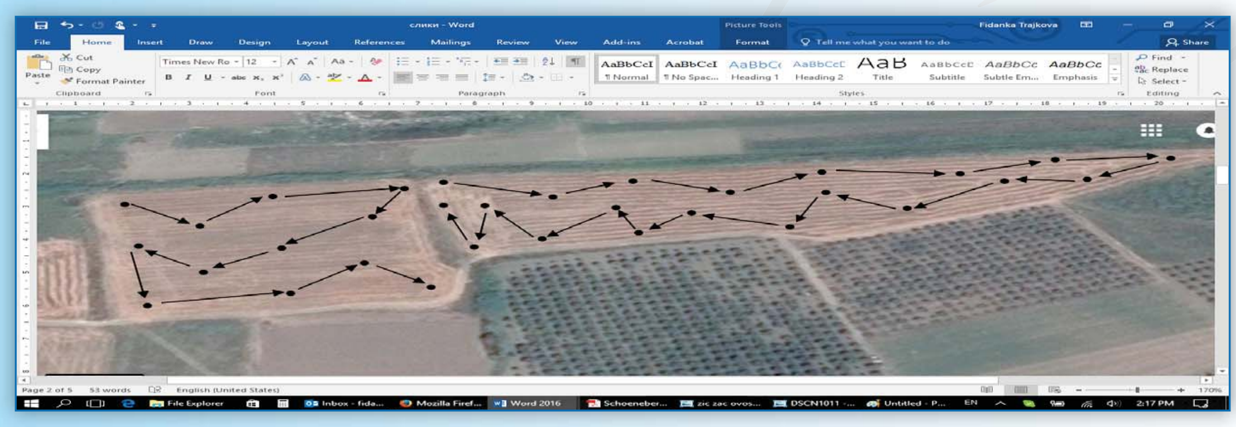


Figure 9. Single soil probing in zig-zag line.

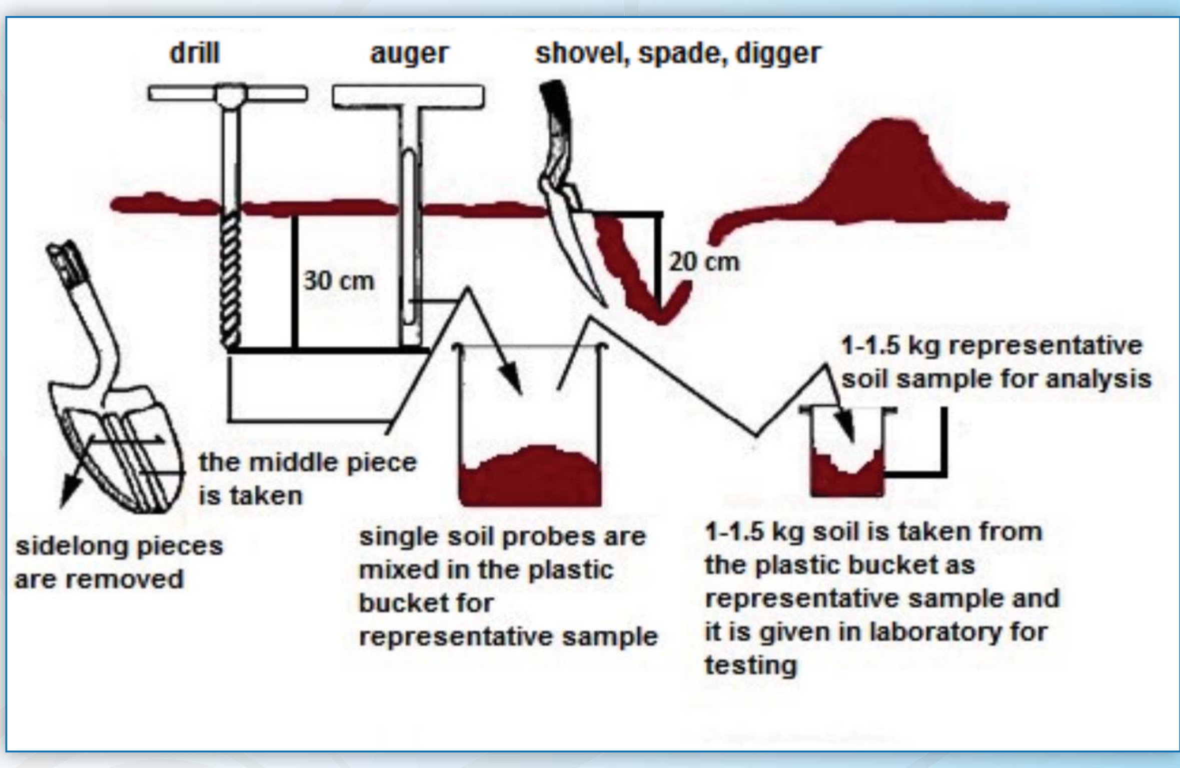


Figure 10. Taking soil probes by using shovel from arable field up to depth of 30 cm (see above) and cutting off a piece for a representative sample (see below).

Before taking soil sample, plant residues which can be found on soil surface are removed.

In case a cylindrical auger is used, the cylinder is pushed into the soil to the depth of 30 cm and 10-20 single probes are taken (Figure 10).

In case a spade is used, a V-shaped hole is made up to the depth recommended for cultivated crop and a piece of soil 2-3 cm thick is cut-off from one side of the hole, in depth to which the sample is take. From the piece of soil that had remains on the shovel we take the middle part with 2-3 cm width and we put it in plastic bucket. This is considered as one single probe which will be a part of the representative sample (Figure 10).

When all the sampled single probes are collected in the plastic bucket, larger pieces of land are broken to smaller ones and plant residues and stones are removed from the soil. This pile of soil is mixed thoroughly to give one final representative sample weighting approximately 1-1.5 kg.

The plastic bag with representative sample is placed in another plastic bag and a paper clip containing sample information is put in as well (farmer name/agricultural company, field of sampling, sampling date and all other information which the farmer/agronomist considers that are important for soil analysis). This bag is taken in a laboratory for testing.

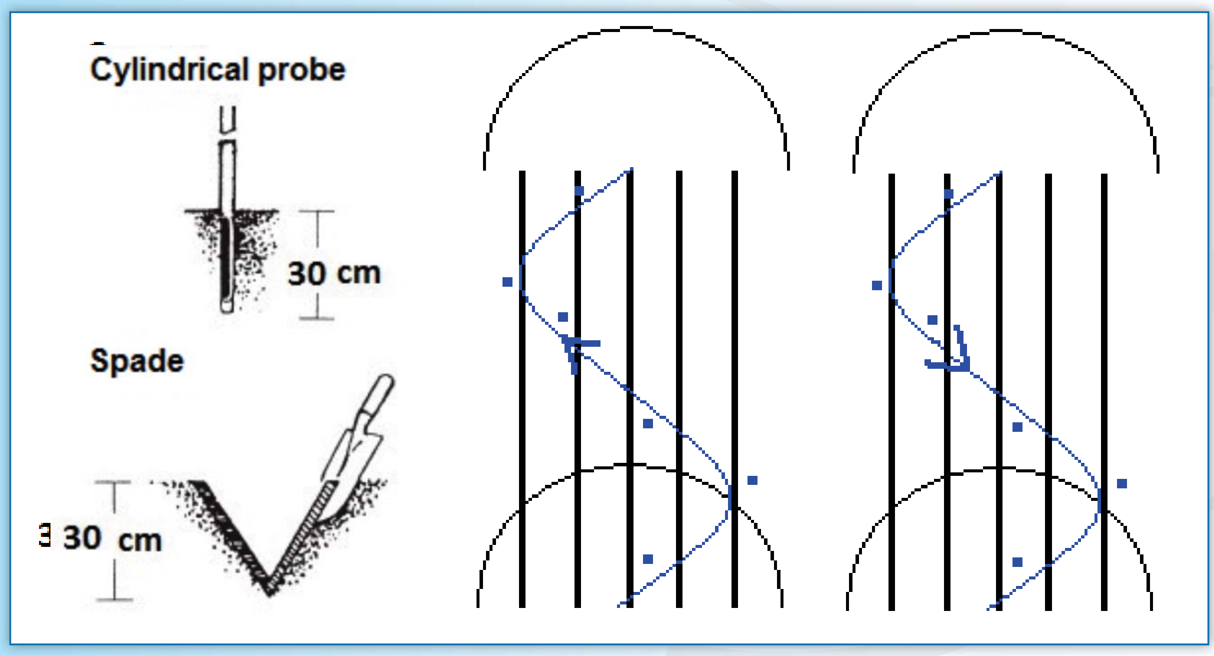
8. Soil sampling from plastic tunnel / greenhouse

Vegetable crops during their development and fruiting stages are uptaking significant amounts of nutrients from the soil, especially if same field is used for growing two or three vegetable crops during one year, which is more common in the recent years. Therefore, besides fertile soil with good structure, for successful production of vegetable crops, there is necessity for supply with of organic and mineral fertilizers in optimal quantities which are properly balanced and applied.

8.1 Soil sampling from plot planned for greenhouse/plastic tunnels

If we want to make soil analysis before establishment a plastic tunnel/ greenhouse, the soil sample is taken according to the procedure for soil sampling of arable land. We must be careful that single probes must originate from the plot parts on which the tunnels/greenhouses will be located.

In case the plastic tunnel/greenhouse is already established, the soil sampling usually takes place before transplanting of plants, at depth of 0-30 cm, following zig-zag line, from the row in which plants will be planted, but never from the farrow between two rows (Figure 11, b)



(a) (b)

Figure 11.

a) Sampling with cylindrical auger (above) and with spade (bellow) in plastic tunnel/ greenhouse at depth of 30 cm.

b) Pattern of soil sampling from plastic tunnel/greenhouse. The single probes must be taken from the row in which the plants will be planted.

8.2 Soil sampling from plastic tunnel/ greenhouse with crop

If the plastic tunnel/greenhouse has installed fertirrigation system, the soil sampling is done between two plants, on 10 cm left or right from the drips, and again on 0-30 cm in depth (Figure 12).

Figure 12. Soil sampling with auger in the root zone of plant (0-30 cm), between two plants, on 10 cm distance from the drip pipeline. The procedure is repeated 10-15 times from carefully selected locations within the plot.

In cases of intensive cultivation in the plastic tunnel/greenhouse:

- Two different crops per year – soil sampling is recommended before each transplanting of plants
- Cultivation of the same crop during same year – soil sampling before first transplanting of plants

In case a problem occurs in the cultivation period due to deficiency or sufficiency of certain nutrient, soil sampling is performed during vegetation of the crop.

Single soil probes are taken from each plastic tunnel/greenhouse no matter the size. If there is no difference in the vegetation of the plants, then one representative sample is prepared from all plastic tunnels/greenhouses which are on the same plot, not bigger than 1 ha. But, in case there is a difference in the vegetation of plants from one to another plastic tunnel/greenhouse, a representative sample is prepared for each plastic tunnel/greenhouse which is different compared to the average.

Once all the single probes are collected in the plastic bucket, larger pieces of soil are broken and plant residues and stones are removed from the soil. This pile of soil is mixed thoroughly to give one final representative sample weighting approximately 1-1.5 kg.

The plastic bag with representative sample is placed in another plastic bag and a paper clip containing sample information is put in as well (farmer name/agricultural company, field of sampling, sampling date and all other information which the farmer/agronomist considers that are important for soil analysis). This bag is taken in a laboratory for testing.

9. Soil sampling from orchard plantation

In order to give maximum yield and quality, trees require adequate soil conditions and proper fertilization. It is important the soil testing to be made before planting of trees in order to assess the initial field conditions and to take corrective and improvement measures, if necessary. On the other hand, soil sampling at certain time interval is performed to check if soil conditions are changing and to give adequate and proper fertilization program for the orchard.

9.1 Soil sampling from field planned for orchard plantation

When soil samples are taken from a field planned for orchard before the trees are planted, 15-20 single probes per hectare are made, each on depths 0-30cm and 30-60 cm, from places where the trees will be planted following zig-zag line (Figure 13). From the single probes, a representative sample for each sampling depth is made and they are taken to laboratory for testing.

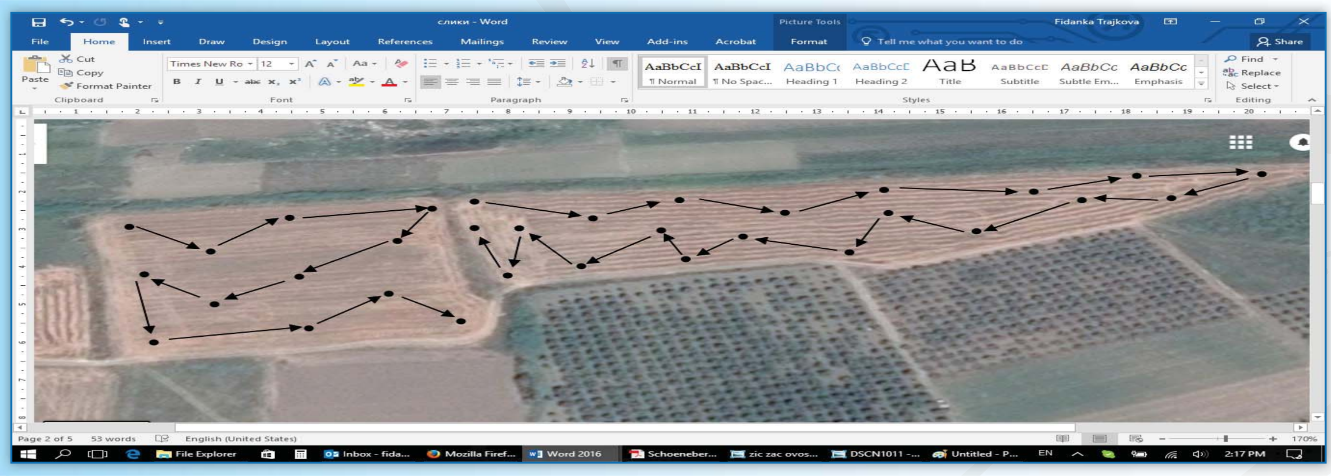


Figure 13. Soil sampling following zig-zag line pattern.

9.2 Soil sampling from established orchard plantation

For tacking the nutrient status in the soil of mature orchard, the soil analysis procedure is performed on every 3 years.

If the trees are equally developed and there are no substantial differences in their yield, then 15-20 single probes per hectare are taken on depth of 0-30 cm and 30-60 cm, alongside the two diagonals of the orchard (line X, Figure 14, a) or by pattern of W-line (Figure 14, b).

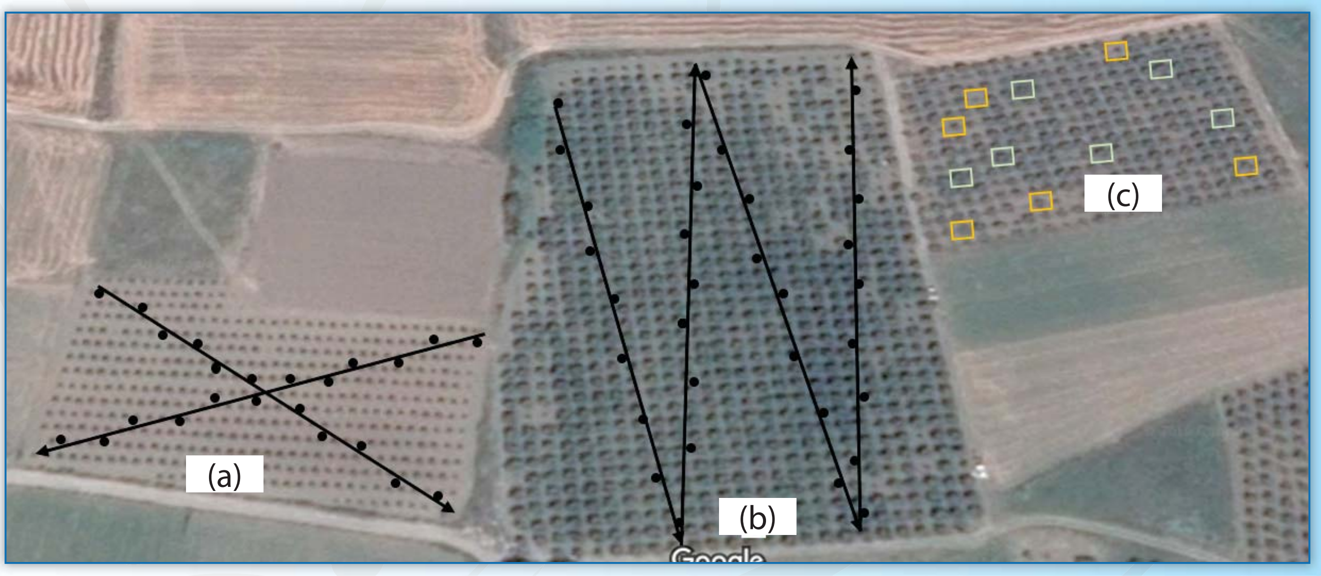


Figure 14.

a) Single probes in mature orchard taken by diagonal pattern (X-line) or
b) W-pattern.
c) The green rectangles represent well-developed trees; orange rectangles represent poor-developed trees. Single soil probes should be taken from them in order to have four representative samples, two from well-developed trees (depth: 0-30 cm and 30-60 cm), the other two from poor developed trees (depth: 0-30 cm and 30-60 cm).

If the trees in the orchard have differences in their size and the yield, in such case 6 well-developed and 6 poor-developed trees per hectare are selected. The single probes are taken separately from the well-developed and poor-developed trees (Figure 14, c). From 1 hectare orchard, two representative sample are prepared from the well-developed trees (depth: 0-30 cm and 30-60 cm) and two from the poor-developed trees (depth: 0-30 cm and 30-60 cm).

Soil samples for monitoring of the nutrient status are taken within the tree crawn, usually on half way inside the tree trunk, in irrigation and fertilization cycle (Figure 15).

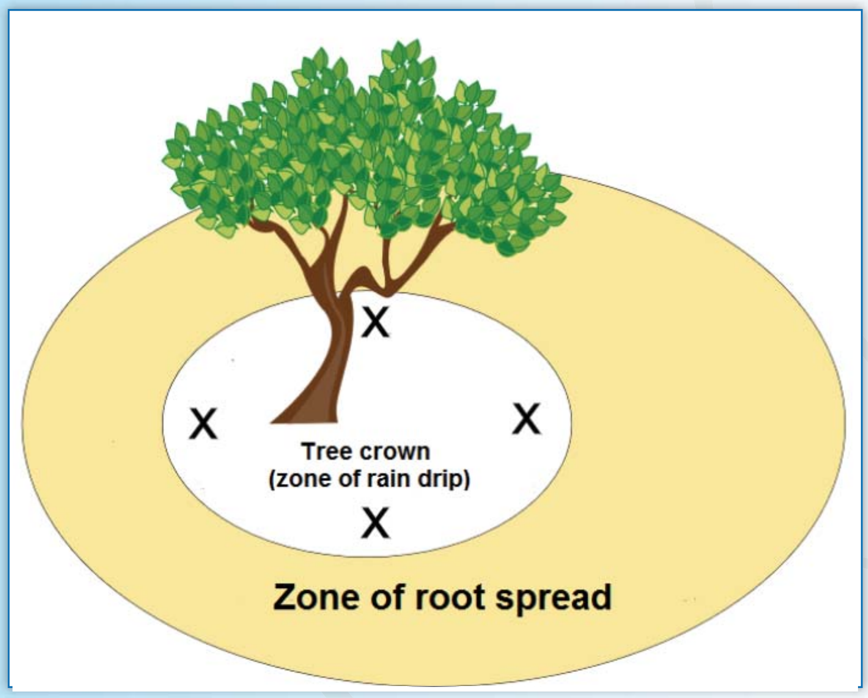


Figure 15.
Soil sampling from individual tree in orchard for control of nutrient level in the soil.

Once all the single probes are collected in the plastic bucket, larger pieces of soil are broken and plant residues and stones are removed from the soil. This pile of soil is mixed thoroughly to give one final representative sample weighting approximately 1-1.5 kg.

The plastic bag with representative sample is placed in another plastic bag and a paper clip containing sample information is put in as well (farmer name/agricultural company, field of sampling, sampling date and all other information which the farmer/agronomist considers that are important for soil analysis). This bag is taken in a laboratory for testing.

10. Soil sampling in vineyards

Vineyards are perennial plantations require suitable soil conditions for successful establishment and suitable fertilization for proper growth and maximum yield and quality.

It is the best the soil testing to be made before planting of trees in order to assess the initial field conditions and to take corrective and improvement measures, if necessary. On the other hand, soil sampling at certain time interval is performed to check if soil conditions are changing and to give adequate and proper fertilization program for the vineyard.

10.1 Soil sampling from field planned for vineyard plantation

A soil analysis of the field planned for vineyard is mandatory before planning of grape vines. Walking in zig-zag pattern in line where grape vines will be planted, 15-20 single probes are taken per hectare, from two depths: 0-30 cm and 30-60 cm (Figure 16). From the collected single probes, a representative soil sample per each sampling depth is made.

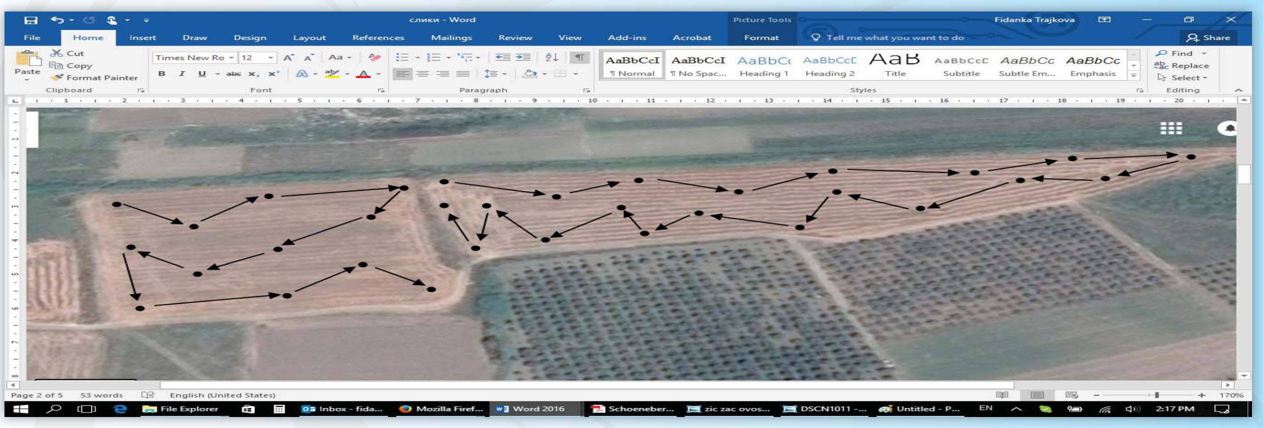


Figure 16. Soil sampling in zig-zag line pattern.

10.2 Soil sampling from established vineyard plantation

To monitor the status of the nutrients in vineyard is the best is first with digging to check the depth of roots. In vineyards with installed drip irrigation system, the probes are taken from the top soil layer of 30 cm in depth (in the grapevine row), about 20 cm from location of the drip. If the vineyard is irrigated by sprinkler or in furrow, the probes are taken between grapevines rows.

Sampling of 15-20 single probes per hectare is made and they give one representative sample. The single probes are collected in zig-zag, X or W pattern (Figure 17).

Once all the single probes are collected in the plastic bucket, larger pieces of soil are broken and plant residues and stones are removed from the soil. This pile of soil is mixed thoroughly to give one final representative sample weighting approximately 1-1.5 kg.

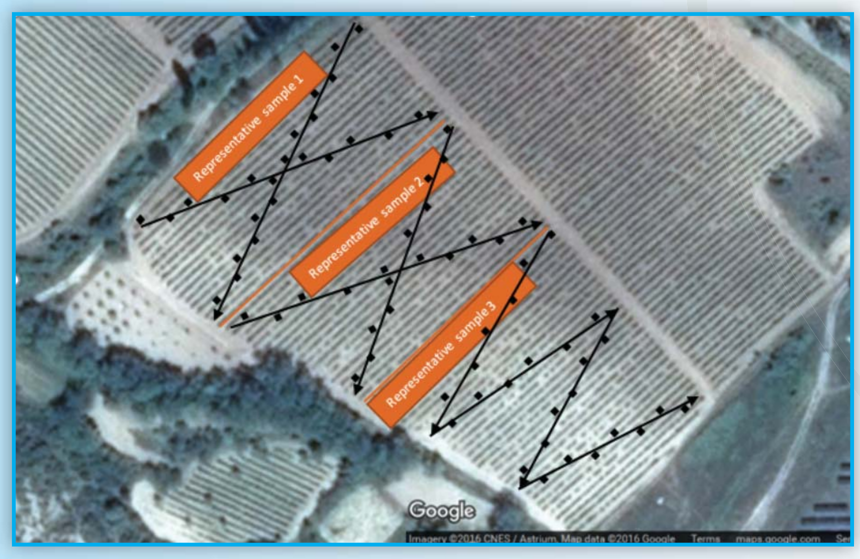


Figure 17.
Taking soil samples by X, V or W-pattern. Due to the size of the plot, there are three representative samples, of which two are made by X-pattern and one by W-pattern.

The plastic bag with representative sample is placed in another plastic bag and a paper clip containing sample information is put in as well (farmer name/agricultural company, field of sampling, sampling date and all other information which the farmer/agronomist considers that are important for soil analysis). This bag is taken in a laboratory for testing.

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Various principles characterize organic farming and among most important the following are to be considered: biodiversity, integrity (harmony with nature), sustainability, maintaining soil fertility, natural control over pest population and integrity.

Biodiversity

Carefully looking over at different living systems, it is easy to conclude that the systems in which multiple living beings are present have bigger chances of survival rather than systems in which only few living beings occupy the territory. Therefore, farms which grow more crops create better living conditions for beneficial organisms that have significant role in pollination, control of population of harmful pests etc. The diversity we are talking about is as important for beneath and for the living beings above the soil, since it is of utmost importance to have optimal living conditions for the beneficial microflora, which operates constantly providing better circulation of nutrients, transfer of organic matter in form acceptable for plants, reduces conditions for diseases, nitrogen fixation etc.

Integrity

Harmonization of agricultural activity is one of the priorities to be achieved if successful farm operation is to be expected. The harmonization process does not consider only adjusting agricultural activities to the natural conditions, but integration of several multiple activities into one. Putted into "ordinary" words, the farm needs to apply activities based on the GAP (Good Agricultural Practice), through growing intercrops, cover crops, growing plants on which beneficial pests will nest and shelter, crop rotation etc. The result of following these techniques will result in reduced amount of expenses for pest & disease control, as well as in reduced costs for maintaining soil fertility. For instance, on a typical organic farm plant production takes place as well as animal husbandry. Animal necessities (fodder, grains) already require application of various growing crops and techniques. The legumes do nitrogen fixation out of the atmosphere, needed for optimal cereal growth while the manure is considered as nutrient source, which are returned to the soil by complex system natural recycle procedure.

Sustainability

In addition to the greater economic stability organic farms are achieving, it is to be pointed that these farms are making additional income by using various governmental funds for environmental protection. On the other hand, knowing that the yields in organic farming, in certain occasions are lower than those obtained in farms applying IPM, the subsidies organic farms are receiving cannot be considered as source of profit. Adding that the number of organic farms worldwide is on the rise while subsidies funds are depleting it should not be understood as too pessimistic if said that subsidies for certain crops will continue to be on the down side and for some of them will seize to exist. Therefore, organic farmers must follow market trends and to respond in order to the customers' demands by producing what they want to buy. Of course, with "acceptable price".

This kind of entrepreneurship makes organic farmers always a step ahead in adopting new production techniques compared to farms producing following IPM techniques (conventional).

Numerous research point to the fact that while trying to adopt production techniques that lead to achieving the ultimate goal (reduced production expenses, obtaining higher percentage of I class production, maintaining soil fertility), farmers that follow organic principles are applying GAP principles much faster as compared to the farms that apply IPM protocol.

Nutrition

If looked a bit more carefully on the way living organisms are assimilating nutrients needed for their development, we'll notice the quite number of similarities but large number of differences as well. Plants, for instance, have the ability through a process known as photosynthesis to synthesize sugars which in different synthetic process are used for production of proteins. Animals, on the other hand, do not possess such possibility so providing energy sources is obtained by consuming plants or other forms of animals.

But, what is common for both living forms (plants and animals) is the necessity for another forms of materials – the minerals. They obtain these materials alongside with sugars and proteins through extraction from the food they receive from the outer world. Plants, through a process of absorption also receive minerals, accompanied with whole bunch of different materials (vitamins, proteins, antibiotics etc.). Still, the absorption system in plants and animals (also known as digestive system) differs a lot. The plants are directly depending on so called "external absorption process of the soil system", which happens in the vicinity of the plant's root system (also known as rhizosphere). This means that plants depend on the processes in which matter is processed in the root zone area with assistance of soil's microflora (which actually transforms the matter in usable form). Animals, on the other hand have their system integrated in their body. This means that they can travel big distances in a search for source of energy, while the plants cannot. And the whole organic nutrition philosophy lays exactly in this. In providing optimal growth conditions for the microbial systems in the soil which are processing different minerals and organic forms in a format usable by the plants. This approach has best results if avoiding to use toxic materials and avoiding to apply bad practices in soil tillage (both are harmful to the soil microbial system).

On the other side of this "organic approach" (the soil systems processing different type of materials and turn them into usable nutritional forms for plants) in the conventional farming system there is a practice to neglect the soil's absorption ability, and to provide the plants with accessible (usable) forms of nutrients directly.

From the aspect of organic farming this approach creates several problems:

- Incorporating huge amounts of fertilizer (soluble nutrient forms once, twice or several times a year) can lead to their concentration around plant's root system, which on the other hand can cause blocking plant's ability to absorb other nutrients, which, ultimately, will lead to imbalanced plant nutrition making it more disease susceptible, vulnerable to pest attack or to reduce the quality of the fruits;

- Absence of activities that contribute to the creation of conditions for development of soil microflora, leads to its reduced number in population. As a result to this plants will have reduced access to vitamins and other forms and materials created by these microorganisms. Furthermore, organic matter content will continue to fall and soil will become dependent on adding synthetic inputs (fertilizers);
- Providing nutrients in conventional fertilization practice in many cases is limited in adding small number of microelements (most often N, P and K), as a contrast to the scientifically proven soil fertility necessity for at least 13 elements; and
- Adding high quantities of soluble nutrient forms (fertilizers) imminently leads to increased cases of weed problems.

Natural pest/weeds control

Regardless of the growing principle (conventional or organic) farmers will always face the problem of controlling pests/weeds. Still, the appearance of weds/pests is not considered as a kind of problem issue. These indicators (pests/weeds) are used to understand the damage level of the eco system in which agricultural production takes place. As frequent and bigger is the weds/pest presence the bigger to the eco system is in place. For instance, part of the weds become dominant if pH value changes, some are emerging as a problem due to soil's structure change and creation of anaerobic conditions, then, others are appearing due to fertilizer overdose etc. There is a belief that insects are attracted by weaker plants, plants that are in poor condition which is a result of an imbalanced nutrition.

Massive numbers of a certain pest, in normal conditions are quite rare. And even it would occur, it is going to be of a short time period, due to the constant presence of their predators which in reasonable time frame are bringing the pest population in normal figures. In damaged systems, in which natural control mechanisms (predators etc.) are not functioning pest problems are frequent and what is worse, they become more intensified and cause great damage.

Today, it is considered that uncontrolled use of pesticide is one of the cause for losing natural balance in the eco-system.

ORGANIC FARMING
BASIC PRINCIPLES & PRACTICES

Biodiversity	Diversification of activities	Sustainability	Natural plant nutrition	Natural pest management	Integrity
Crop rotation	Crop rotation	Crop rotation	Crop rotation	Crop rotation	Buffer zones
Green manure	Manure	Manure	Manure	Manure	Record keeping
Cover crops	Composting	Composting	Composting	Cover crops	
Manure	Inter cropping	Inter cropping	Natural fertilizers	Composting	
Composting	Farm planning	Biological control	Foliar fertilizers	Inter cropping	
Inter cropping	Mulching	Farm planning		Biological control	
Farm planning		Manure		Farm planning	
Buffer zones		Composting		Hygiene	
		Mulching		Soil tillage	
		Buffer zones		Fire	
				Natural pesticides	

Integrity

The term integrity relates to the steps that are taken on certain place in order to assure the consumers that they are receiving the kind of quality they are paying for. The consumers have every right to expect that not only the food that is declared as organic responds to that type of agricultural activity, but that they are protected from any other kind of pollution.

Such expectancy is provided by vast number of organic farmers by respecting and following the organic farming principles. Yet, still, there are producers who due to the nature of the production process are required to fulfill additional conditions. In this context, regular bookkeeping is a must in organic farming, yet not welcomed by all of the farmers as they find this activity waste of time. When we talk about additional activities, it is to be known that these activities refer to the possibility of building buffer zones, which need to prevent the penetration of chemical agents applied on the neighboring plots, where conventional farming is in practice.

Crop rotation planning

This term refers to the change of growing crop on one plot in period of time. The crop rotation is organized to maintain soil fertility and to contribute to the control of pests on a tolerant level. GAP in organic farming is especially related to good rotation scheme, especially to legumes. They provide great nitrogen quantities needed for the future crop (i.e. corn, which needs nitrogen in large quantities). There several kinds of crop rotation, depended on the soil type and weather conditions in certain area.

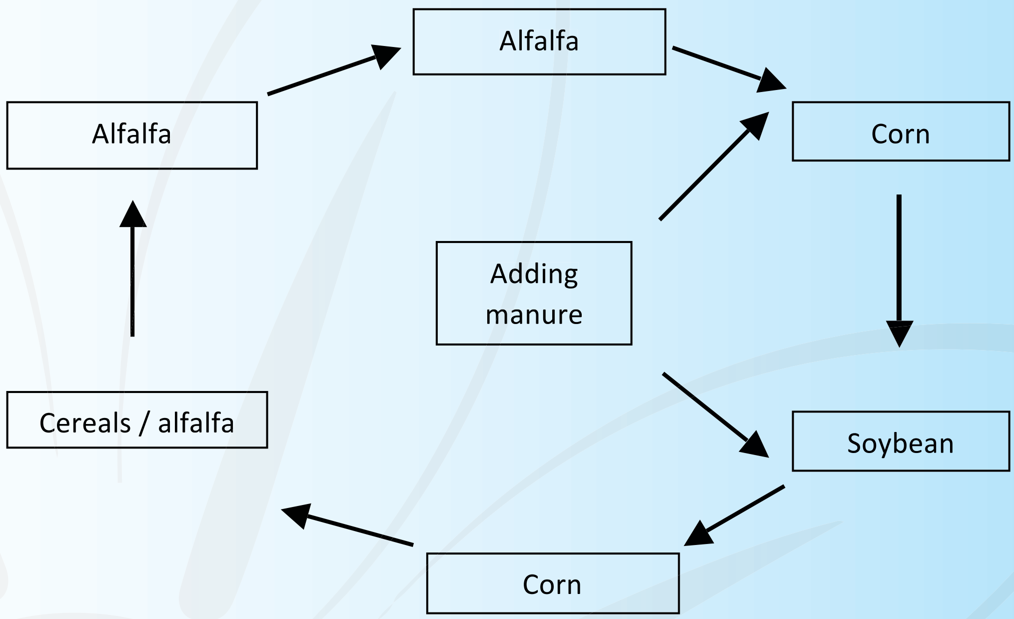


Figure 1 - Crop rotation in organic farming adjusted for corn growing

A close overlook on the scheme can help to understand the philosophy of this type of crop rotation:

- Legumes are fixing nitrogen, needed for future crops, which do not possess such ability;
- There is a breaking up of a development cycle to the specific pests (specially to wire worms, which can cause significant level of damage);
- The development cycle of several diseases is broken up;
- Improved control over perennial weeds (by having cereal crops; while annual weeds through cuttings of alfalfa);
- The manure is applied just before planting of the corn takes place (corn needs large nitrogen quantities);
- Cash crops can be sold on the market or to use on the farm (added value through their use as a feed to the animals, of which wool, meet, milk is expected as main product).

Setting proper crop rotation scheme for vegetables is a different story. Regardless of the fact that these plants are different than the small grains it is also important to consider fixation of the nitrogen from the atmosphere. It is recommended to set 8-year crop rotation cycle. In this scheme:

- Potato, comes after the sweet corn. Research results point to the conclusion that the corn is one of the crops that contribute for the potato to achieve high yields;
- Sweet corn, comes after cabbage family crop, due to the fact that the corn does not tend to have reduced yields when cabbage family crop precedes it. Furthermore,

cabbage family crop can go along with legume crop, which will be used as green manure crop. After this green manure crop is to be inserted in soil next spring, it will be ideal for the development of sweet corn;

- Cabbage family crop, inherit the peas, as this crop leaves the plot quite early, leaving the plot "clean" and with possibility the plot to be used for production of green manure;
- Peas, comes after growing tomato as this crop needs growing in lanes and due to the possibility the tomato to be sown in substrate resistant to low winter temperatures and will not cause problems with emergence and development;
- Beans, comes after root crops as it is not susceptible to their presence (carrot for instance);
- Root crops, can be grown after potato. These crops are considered as good soil cleaners (the area on which they are cultivated can be maintained clean without major problems).

This 8-year cycle for vegetable crops is presented on figure 2.

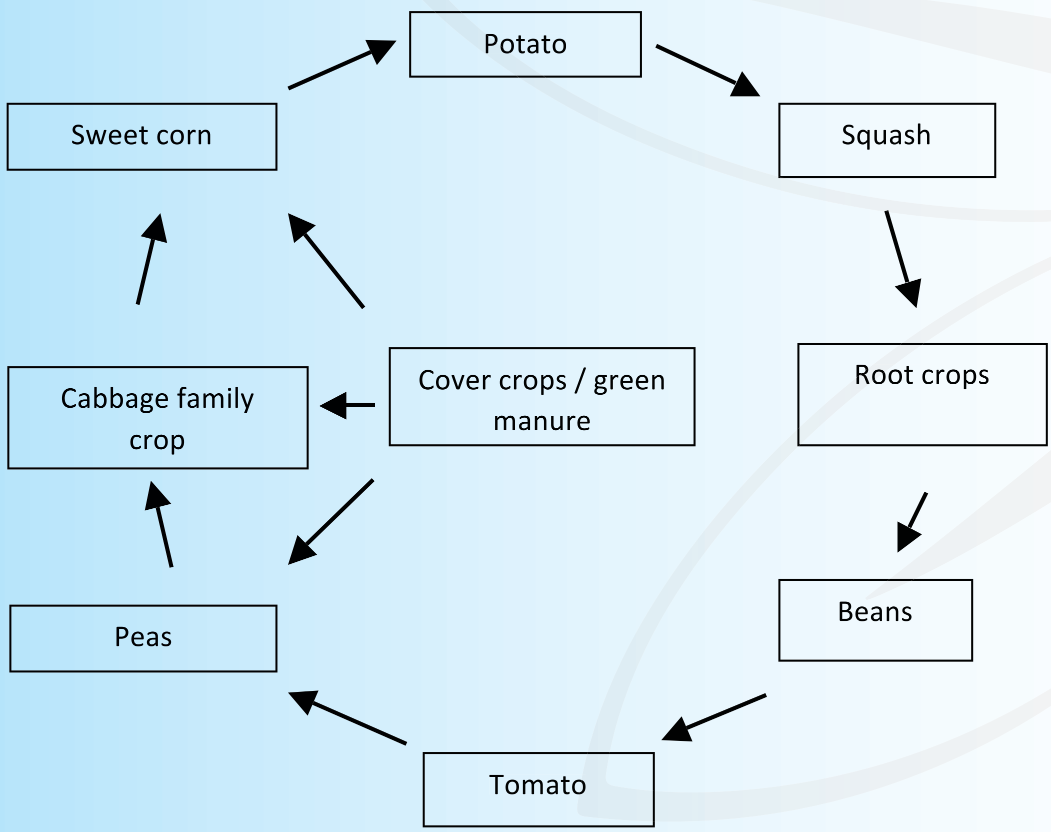


Figure 2 – Crop rotation for 8-year crop rotation

Other than this possibility, there is another crop rotation principle, based upon 4-year exchange of crops: leaf crop→fruit crop→root crop→legumes→repeat of the cycle.

Not less important is the proper section of pre-crops for vegetable crops. The preview to the scheme of suitable pre-crops is given in the table 1.

Table 1 – pre-crops preview for vegetables

Crop	Pepper	Tomato	Cucumber	Carrot	Onion
Pre-crop	Peas, bean Early tomato Cabbage Watermelon	Peas, bean Early tomato Cucumber Watermelon Onion, carrot Grass	Tomato Onion Early potato Legumes Winter cabbage	Cucumber Potato Cabbage	Tomato Winter cabbage Early tomato

Green manure and cover crops

Green manure is a crop that will be plowed during vegetation season in the top soil layer in order to improve soil characteristics. Unfortunately, this cropping techniques has been abandoned for number of years for the sake of growing crop all season long. However, lately there are incentives for commercial growth of green manure crops as main crop.

Self-emerged cover crops (legumes)

Main reason for establishing cover crops is for preserving soil characteristics and nutrients within it. Both techniques (green manure & cover crops) are contemplating quite well, considering that cover crops are mainly used for green manure before main crop takes place.

Self-emerged cover crops (legumes and grass)

Main effect is obtained if cover crop takes place out of the main growing season, or along with the main crop, while best performance result will be achieved if the cover crop has nitrogen fixation characteristic.

Peas as cover crop in vineyard

Manure and composting

Manure and compost traditionally represent most applied forms of organic fertilizers. Ideally, on a typical farm both plant and animal production takes place, so taking manure to the field can be considered as a part of the closed cycle of nutrient recycling. On the other hand, in reality, farms that grow plants are not usually associated with animal husbandry activity, hence the manure needs to be brought from elsewhere.

Such practice raises concern with inspectors and producers as large quantities of manure are produced only on large farms. And on those farms not every production element is under strict control (kind of feed given to the animals, possibility for heavy metal pollution, antibiotics, pesticides, etc.). Hence, use of manure from large farms is not allowed in organic farming.

Another issue that is raised quite frequent is food safety. In situation when concern over microbiological food safety is on the rise, so is the use of unfermented/raw manure (primarily in the USA and EU countries).

Machine for compost mixing

One of the best principles for manure application is by applying it composted. This procedure stabilizes the nutrients, creates favorable conditions for microbial growth and finally, has positive effect over the soil and growing crops. Perhaps, one of the most positive things is the fact that the composting can be performed on the farm itself. The by-products (compost tea) have special application in organic farming. The preparation for composting starts by collecting materials rich with nitrogen (so called "green part"). Collected material needs to be chopped to 3-5 cm length. After this procedure is performed the mixture is mixed and water is added to the optimal capacity. The fermentation takes 3-6 months for which time the microorganisms will digest the organic matter, the pile warms-up itself thus achieving "low temperature Pasteurization". Bu this, the largest number of harmful microflora is destroyed. The composting mixture should not be compressed as for the proper fermentation oxygen is needed. The place where fermentation takes place should not be exposed to direct sunlight. If the fermentation process is uninterrupted or in any case without development of undesired processes, the composted organic material is with fine odor, has tiny structure, slightly acid pH, has lots of macro and micro elements, vitamins etc. Due to its porous structure the composted material has light specific weight, which reduces transport costs. As comparison, if not composted manure is used, necessary amount of manure that needs to be applied is almost 30 t/ha, while if composted manure is used, the total amount does not exceed 10 t/ha.

The preview to the main characteristics of different kind of manure is given in table 2.

Table 2 – Characteristics of different type of manure

Kind of animal	Ratio sold : liquid part	Humidity	Manure		
		H_2O	N	P_2O_5	K_2O
Cattle	80 : 20	85	5,0	1,3	3,7
Pigs	60 : 40	85	6,4	3,0	5,4
Sheep & goat	67 : 33	66	11,0	3,5	10,8
Poultry	100 : 0	62	14,9	7,0	3,5
Horse	80 : 20	66	7,4	2,2	6,5

Source: Brady, The nature and properties of soils (1974)

The approximate content of composting mixture is given in table 3.

Table 3 – Approximate content of composting mixture

Organic matter	N	P	K	Ca + Mg	pH	Ratio C:N
30 - 70	0,3 – 1,0	0,2	0,8	2,5 – 3,5	7,5 – 8,0	<12:1

Source: Sarapatka, Urban et al. (2009)

The preview to the most frequent materials used for composting and C:N ratio are given in table 4.

Table 4 – Most frequently used composting materials

Green component	Ratio C:N	Brown component	Ratio C:N
Fresh manure (with straw)	30:1	Straw	70-100:1
Fermented manure	15-20:1	Corn stalks	60:1
Cut grass and green leaves	15:1	Dry leaves	50:1
Garden/lawn weeds	20:1	Saw, wood, paper	200-750:1
Food residues	15:1	Bark (hard wood)	100-400:1
Fruits remains	25-40:1	Bark (soft wood)	100-1000:1
Alfalfa hay	12:1	Moss	58:1
Clover leaves	18:1	Branches	200-400:1
Urine (cattle, sheep)	4:1	Rice hull	110-130:1
Blood meal	3:1	Newspaper paper	400-850:1
Coffee dry	20:1	Pine leaves	80:1

Biological pest control

Organic farming is directly related to the presence of: beneficial insects (predators & parasites), vectors for disease spreading, birds that feed on other organisms and with organisms that that have their role in controlling pest population. If these organisms can be considered as control tool it is to be stated that this tool is often used along with other agricultural techniques and methods that keep the pest number under control. There are even cases in which due to strict follow-up of the bio-control procedures, farmers do not undertake any other additional activity for pest control.

Of course, there are opinions which define successful biological control in organic farming as direct benefit from undertaken activities aimed for maintaining or improving soil fertility. The exchange of crops grown in one area, use of cover crops as well as other practices for soil tillage, contribute to the achievement of the permanent control over pest presence in certain area. It should be remembered that absence of use of pesticide has positive effect on biocontrol.

Lately, farmers are beginning to purchase and later to release organisms used in bio-control (lady beetle, wasps of Trichograma family, and in certain cases domestic animal are used: geese, ducks, chicken, sheep) in controlling weeds.

Lately, farmers do have a practice to build temporary or permanent shelters where beneficial insects, spiders and other beneficial organisms can develop their population without disturbance. Such practice is known as **farmscaping**.

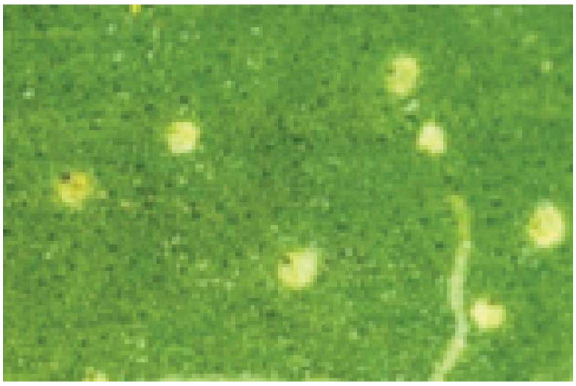
Predators' natural habitat

Irrelevant to the applied growing technique (conventional, IPM or organic) farmers will always face pest problem, for which they lose time and money. Still, in organic farming the presence of diseases and pests are not considered as a kind of punishment (loss).

They are understood as indicators of the level of disturbance in which certain eco-system is.

Predator (P. persimiLis) attacks pest (T. urticae)

The bigger and larger their presence is, the bigger disturbance in the eco-system. For example, part of the weeds are becoming dominant if soil's pH factor changes, others are becoming problem if disturbance of soil structure and appearance of anaerobic conditions occur, yet others appear due to excessive use of fertilizers. There is a belief that, in fact, insects are attracted by plants in poor condition, which occurs due to poor nutrition.



Miner eggs

In normal conditions, pest outbreak occur very rarely and short in time. This is due to the presence of their natural disease and enemies which in case of their drastic growth in population, bring their numbers back to normal. In the systems which irreversibly break-up these mechanisms, problems with the insects are frequent and what is of a concern they cause great damages.

Uncontrolled use of pesticides is considered to be the main reason for loss of balance in the nature, for which only use of natural pesticides is allowed. And only in case of emergency.

Lady beetle as predator

Inter cropping and associated cropping

Growing two or more crops side by side is one of the strategies used to increase biodiversity.

Associated cropping of beans, flower and lettuce

In case this principle is applied on large plots of land, with use of highly mechanized equipment it is called inter cropping. If in case this principle is applied on small plots it is called associated cropping. Typical example is when we grow beans and corn. In this system beans contributes to the fixation of nitrogen, while the corn serves and support to the beans.

Cover crop in orchard

Hygiene

Can be presented in various forms i.e.:

- Removing, burning or deep covering of plant residues which might be infected with disease or hold pest eggs;
- Destroy grass cover used for breeding of harmful insects;
- Cleaning the equipment of weed seed before entering on a new plot;
- Sterilization of pruning equipment.

Fully respecting mentioned forms can significantly reduce problem presence on a long run. However, which action will be implemented should be carefully chosen as implementing one method, even in best intention might cause problem in other form. For instance, maintaining the soil "clean" (no plant cover) can lead to erosion, loss of biodiversity etc. Well prepared and educated farmers can recognize this jeopardy and will use mentioned forms only in a case of emergency, rather than applying them on a daily base.

Soil tillage

If properly implemented, this technique can contribute to the achievement of many positive outcomes: weed control, proper management of plant residues, soil aeration, keeping manure and other forms of natural fertilizers.

While conventional farmers are using chemicals regularly if to achieve above mentioned, organic farmers are acting in accordance to the organic principles and orient themselves to improved soil tillage. Recommendations about improved tillage are in relation to keeping plant residues and applied amount of fertilizers in top soil layer (bio active soil layer), rather than inserting them in deeper soil layers where anaerobic conditions are unfavorable for proper organic matter conversion. Therefore, it is not too hard to conclude that soil tillage in organic farming is equal to an art. Farmers that grow arable crops use wide number of practices: shallow cultivation – applied from sowing 'till plants reach several centimeters and contribute to the delay of weeds' development, thus enabling the plants to "claim" the area. If conditions are favorable and cause weed emergence another set of machinery is to be used (chisels, robots etc.) who have the ability to operate close to the plant.

Determining when the machinery is to be used is real art in managing organic farm, since each use of the machinery to bring in order things that out of control means additional costs. Therefore, knowing plants biology (when they emerge, favorable growing conditions) for experienced farmer can mean significant cut in costs. Also, too frequent use of the machinery reduces the content of soil's organic matter since too frequent tillage leads to the higher oxygen level, which provides conditions for quick decomposition of the organic matter in deeper layers, which if conditions were normal, would happen on a longer run. Excessive use of machinery lead to reduced number of worms and destroying their tunnels made by their movement through the soil.

Mulching

Quite frequent applied technique in organic farming. Large quantities of organic matter (straw, old hay, saw) are spread between the rows. By mulching we are regulating the soil's temperature and humidity, reducing favorable conditions growth and development of weeds and we're adding organic matter to the soil.

Other form of mulching is laying plastic foil, but it needs to be removed after growing season is over. Its use provides control over the spreading of the weeds over large area.

Use of plastic foil for mulching

In many cases organic farming is described as a system in which very little as an input arrives from outside of the farm. Of course, this is a false impression as there are farms that are totally dependent on materials provided elsewhere.

For instance, production of strawberries (annual variety), by using plastic foil as a cover, irrigated by drip irrigation system and use of soluble fertilizers. As presented, almost everything needs to be purchased out of the farm since it does not produce any of the necessary input. By the end of the growing season the plastic foil is removed from the soil while organic matter goes through regular treatment. Ideally, if conditions are favorable, second crop included in subsidy system might be introduced which will increase the level of exploitation of the soil. Especially if the subsidy for growing certain crop is higher than the others.

CERTIFICATION PROCESS

Right from the very beginning a question imposes itself, why the necessity to certificate? Why, despite common expenses related to production, there is a necessity for another one?

The answer to these questions, no matter how simple is, still holds certain level of complexity for it needs to provide an answer to the following: certification process is a necessity for obtaining regular control over the production process and to issue an insurance to the customers that it is safe. The latter is of utmost importance since the buyers want and have the right to know that what they are paying for is exactly the one what they are looking for.

Regardless of the contradictory of the arguments as they may appear, the certification process offers security to the producers as well, since through the follow-up principle, in case of necessity each and every one can see who and at what stage had made a mistake. Finally, the certification process provides security to the trading companies too. Since data related to the production must be kept for 5 years it is easy to determine if and who had made a mistake during production, processing or marketing.

Origin of the certification body

In accordance to the existing regulations, each country provides a possibility for domestic or foreign certification body to provide services on its territory. It is also important to know that both bodies (domestic or foreign) must follow the international regulations for inspection and certifying and to the domestic legislature for conducting similar control. In accordance to our regulation, every foreign institution which provides inspection and certification, can organize identical activity in the Republic of Macedonia after applies for and receives and accreditation from the Institute for Accreditation of the Republic of Macedonia. And to be granted one, it must be registered for conducting such activity on the territory of the Republic of Macedonia and to have at least one employee.

A basic dilemma rises in front, is there any advantage or disadvantage if there is only domestic or only foreign certification body? Well, both models have its own positive and negative sides.

Firstly, in case there is only domestic certification body. First step this institution must make is to adopt the working methodology and this has to be in accordance with the international guidelines for work of inspection/certification bodies. Then, a request for registration is submitted to the Institute of Accreditation and finally a request for enlisting in the register of companies that provide such services is submitted. By including into the Register of companies this body is given the permission to conduct inspection and certification activities on the territory of the Republic of Macedonia. If the body intends their certificates to be recognizes internationally, the body addresses to the relevant institution in the country in which it wishes its certificates to be valid.

Secondly, there is case when foreign inspection/certification body registers a branch office in the Republic of Macedonia, having at least one employee. In this case, the inspection/certification body submits a request to the relevant authorities to be granted accreditation to work and then to be listed into the Register of companies that provide inspection/certification activities. The certificates that are issued by this organization are valid on the territory of the Republic of Macedonia and in the territories of the countries in which the body has obtained permissions to operate.

Selection of certification body

Which certification body will be selected is up to the customers to decide, based on the marketing decision on which market they wish to sell. Other elements that may make the decision is the price, the number of countries that recognize the certificate etc.

Farmers should thoroughly look for various elements about the certification body before they apply for inspection. This is due to the fact that some farms tend to believe they're suitable to turn organic, but in fact they are not. And once they submit an application for inspection bill will arrive. Therefore, it is best for the farmers to check their compliance to the organic principles once they start feeling they would like to turn to this kind of farming.

It is to be remembered that certification is on annual base. It is renewed each year.

Filing an application for inspection

After the moment of deciding which body will conduct the inspection, the farm submits an application (usually a document downloaded from the body's webpage).

Farmers are obliged to possess all data related to the history of the farm, preview to all of the products for they require certificate, in case processed product is concerned they need to possess full preview to all ingredients that compose the final product, storage rooms etc. There are separate questionnaires meant for special kind of clients (green house producers, animal husbandry farms, distributors…).

Inspection

After filing the application, the body sets reasonable time frame to their inspector to perform inspection. In order to do so, the selected inspector talks to the farm owner and set time and date for the visit. Until that moment farm owner needs to complete all required documentation. In case the owner is not available in the set date and time, he is free to refuse the inspection on the proposed date, but will have to wait on the inspector to set another one.

Once date is set and inspector arrives at the farm, the first step is to check the documentation: records on crop rotation practice, fertilization, soil tillage, soil analysis, etc. After this step is over, the inspection continues on-site.

After having all checked the inspector prepares report in which he explains his views about farm status. This report is submitted to the certification body and forwarded to the certification committee for review. The committee holds meeting upon schedule or on-demand. Based upon the certification body's policy, the decision of the committee can be:

1. Approved;
2. Approved with conditions that must be met prior certificate is to be issued;
3. Approved with conditions that must be met in set time period;
4. Denied. Reasons are noted in the document;
5. Delayed. There is more additional information needed before final decision is to be made.

The decision, if a farm is granted a certificate or not is delivered to the inspector that had performed the inspection. In any case, the inspector must not express an interest of the committee's final decision. After committee's decision the applicant receives notification. If there are things that must be met, the applicant signs and obligatory document or an agreement by which he/she accepts the terms and obliges to meet each and every one of them.

The agreement and the contract must be returned to the certification body.

In case conditional agreement is issued, the applicant must meet the requirements. In case these requirements are of significant character, another inspection might be scheduled. In case the application has been denied, the applicant has a right to appeal, following body's procedure.

After certificate is delivered, the operator is entitled to attach organic logo on its products and to market them as organic.

Preparation of pesticides of plant origin

Nettle – (against aphids) 1 kg of fresh collected nettle (or 150 g dry) is put in 10 L pot. The nettle can be in blooming stage but with no seed. The nettle is covered with water. The level needs to be 4-5 cm above the highest plants. It is preferable the water to be collected from rain. The pot is covered and left for 12-24 hours. After that period, strain the liquid and so undiluted use for spraying. Places where aphids are located should be well wet. Spraying is repeated several times. Freshly made preparation there are tiny needles of formic acid which destroy the aphids. This preparation is suitable for smaller presence of aphids. Should their presence be with greater intensity, use of more effective means is recommended.
Tomato – (against cabbage moth) Take 100 g of fresh leaves of tomato and cover with 1 L of water and leave to soak for 3 h. After that the water used for spraying. Spray every second day during the laying of eggs of cabbage moth. The smell of tomato rejects the cabbage butterfly moth.

Tomato – (insecticide) Use 10 L of water to placed 1 kg of fresh or dry fern 150 g and left for 24 h to stand to soften. After that mass boil for 30 minutes and then strain the liquid and cool. It is used undiluted. Spray in winter during quiet weather. The liquid is stored in wooden or plastic keg.

Tobacco – (aphids) From the extraction of tobacco waste from getting dark liquid, 100 L of water is placed 5 L of liquid tobacco and 2 kg potassium soap. Mix well and then use for spraying.

Onion – (small spiders) Take 20-50 g onion peels and pour 1 L of water and leave 4-7 days. Then strain the liquid and spray undiluted. Spray against spiders and preventive against: powdery mildew, fire blight and fusarium. Besides plants, it is can be used for spraying on soil.

Compost - Made from the plant remaining used against: the compost from rotten fruits attacked by *Monilia* prevents attack of this fungus; Tomato compost made from parts attacked by powdery mildew prevents infection of the new powdery mildew on tomato.

Chamomile – If sown with cereals, enhances plant growth. Is believed that one chamomile plant protects 1m^2 area against the white worm.

Marigold - Suppresses the white worm with its smell that emits from its root, so worm escapes from the smell. It is especially used in symbiosis with carrots.

Garlic – Used as repellent against white worm. Garlic sprinkled among strawberries helps them to be more robust.

Rennes - Sprinkled on the edges of the potatoes helps getting healthy tubers and sprinkled besides cherry prevents against *Monilia* and rot.

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