My lecture is dedicated to Dr. M. G. M. Bruggenwert,

to my departed friend and supervisor

THE EFFECTS OF EM ON SOIL AND PLANT CHARACTERISTICS

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ABSTRACT

The concept of Effective Microorganisms (EM) has opened a new age in soil, agricultural and environmental sciences. Therefore some theoretical aspects were studied (factors affecting inoculum success, synthesis and decomposition).

The quality of activated EM and the process of EM activation were characterized by biological and chemical monitoring in fermentation experiments. Bacteria, micro-fungi, actynomycetes were able to grow side by side during EM activation and reaching high concentrations their co-existence proved to be stable. Dehydrogenase enzyme activity and substrate-induced CO_2 production proved to be good indicators to characterize the effect of activated EM on soil vitality. Organic acids were produced which decreased the pH value.

The efficiency of activated EM was tested in different soils. The effect of EM on plant growth was studied in pot experiments. Experimental conditions were controlled thus the efficiency of activated EM in different soils could be characterized in details. EM application stimulated plant growth. The effect of EM had an optimum, which was different in various soils. The optimum EM dose depended on the original soil characteristics.

The goal of the present lecture is

- to study some theoretical aspects of EM technology,
- to characterize the process of EM activation and
- to evaluate the effects of activated EM on soil and plant characteristics.

THEORETICAL ASPECTS

Concept of EM

The concept of Effective Microorganisms is based on the co-existence and co-prosperity. It was Prof. Higa who realized that co-existing microorganisms, which support each other, could create a prosperous soil life. EM, containing co-existing and co-prosperous microorganisms, is able to create a vivid soil life, if the natural and environmental conditions are also appropriate.

The living conditions of microorganisms greatly influence the vitality of soils in the temperate region. When the average and optimum living conditions are compared then the number of microorganism is 100 – 1000 times higher and the living biomass of microorganisms is 5 – 10 times higher under optimum condition (***Table 1***). These huge ranges clearly prove that optimization of soil life, the vitalisation of soils has a large biological potential.

EM, the community of microorganisms

The community of a living space can be defined as the sum of organisms co-operating, directly or indirectly, with each other in a habitat. Community is characterized by a generic diversity. The number of co-operating species

can be high, medium or low. The communities are not taxonomic categories or units, since they can be very complex and bacteria, fungi, yeast, etc. can take part simultaneously in their structure or functioning. These are inter-specific communities, whose members are connected by co-operation for a shorter or longer time.

Pioneer communities degrade the organic residues first when an inoculum is added to the soil. These pioneer microorganisms have to deal with the resistance of environmental conditions (extreme salt concentration, accumulated inhibitors, low pH value, low water potential, antibacterial compounds, organic or inorganic toxic chemicals, etc.). If the pioneer community started to multiply then it may become the main biological barrier for other newcomer organisms.

The communal metabolism serves as the fundament of the community of microorganisms. Microorganisms get their nutrient and energy supply from their environment. The energy sources and essential elements determine the structure of microbial communities.

Successive communities will propagate when the environment cannot ensure optimum living condition for the pioneer communities any more. The microbial communities modify their environment too. During autogenic succession the living community modifies its environment in such a way that the environment becomes more appropriate for other species. During allogenic succession one community is changed to another community due to the environmental changes caused by non-biological reasons.

The large genetic diversity of a microbial community, which also represents a great gene pool, always characterizes the complex and wide-ranging activity of the community. This is true for vital soils and particularly for EM1 inoculator.

Factors affecting inoculum success

Very many factors can influence the success of a microbial inoculator in the soil (***Figure 1***).

Inoculum factors include considerations at all stage of inoculum use (strain selection, culturing of the strain, carrier preparation, mixing of the culture and carrier, maturation, storage, transport and application, etc.).

Among *soil physical properties* the particle size - and pore size distributions are the most important since they determine the water and air content, which are important for microbial life. The level of moisture at which the cells are maintained is a key factor in the success of an inoculum. This is particularly important in tropical latitudes where desiccation of (e.g. rhizobial) cells must be avoided.

Soil chemical factors ensure the energy and nutrient supply. The capacity properties (quantities of organic and inorganic components) and the intensity parameters (pH, redox potential) determine together the availability of nutrients for microorganisms and plants. Acidity plays an important part in determining the survival and success of an inoculum in many soils. The high availability of aluminum provides the biggest problem for the soil biota in very acid soils. Restricted root systems (due to low nutrient content and availability) may decrease the success of the microbial inoculation. This is particularly true for phosphorous, which is deficient in most tropical soils.

Soil biological factors represent the interactions among the microbial inoculum and soil fauna, soil microflora and soil viruses. These soil biological interactions can greatly influence (support or limit) the success of a microbial inoculum.

Plant factors characterize the soil / plant interface, where the microbial activity is very vivid. An efficient microbial inoculum generally increase the vitality of the soil / plant interface.

Environmental factors cover those parameters which have high relevance in agriculture and which are generally difficult to modify.

The microbiological behavior of a soil is based on the indigenous microbial community, on its concentration and composition. This capacitive property is changed when the soil is inoculated. It follows from this that the composition and concentration of an inoculator (inoculum factors) are fundamentally important when one wants to increase the vitality of a soil.

Concept of syntropy

The increased vitality of soil life can be characterized by the concept of syntropy. According to Murányi syntropy can be defined as the enhanced process of synthesis by co-existing and co-prosperous microorganisms. Syntropy is connected to synthesis as well as to entropy.

Soil – plant systems exchange both energy and matter with their surroundings and are consequently open

systems thermodynamically. They should therefore tend towards a steady state described by non-equilibrium thermodynamics and characterized by minimum production of entropy. Entropy is a thermodynamic quantity, a measure of randomness or disorder in a system. The theory surrounding the principle of minimum entropy production provides a good analogue of the behavior of natural and agricultural ecosystems subjected to perturbations. Entropy-increasing processes (decomposition) are those that degrade complex, ordered structures of large molecular weight to small molecules such as CO_2, NH_3, and H_2O. Synthesis processes such as photosynthesis that build small molecules into larger ones lessen entropy (***Table 2***). These ordering processes are permitted by thermodynamic work performed when heat is transferred from the sun. They depend critically on the capacity of the system for self-organization, which is identified with its biological potential. Several of the small molecules are environmentally undesirable in excess. This, together with the theoretical considerations above, suggests that minimum production of entropy should be a criterion of sustainability. It implies that agricultural systems should be allowed to become steady states where possible and that maintaining the biological potential is essential. An 'audit of small molecules' is suggested as a way of assessing sustainability.

The sustainability of agricultural systems depends on maintaining a proper balance between synthesis and decomposition.

Synthesis of growing plant and decomposition of dying plant

The soil/root interface is a particular region, where the process of synthesis (plant growth) and the root-induced soil changes can be studied at the same time.

Synthesis. Vigorously growing plants decreased the pH in the rhizosphere soil up to about 2 - 3 mm (***Figure 2***). Strongly acidified layers could be detected close to the root surface. The acidity status of the rhizosphere was quite different from that of the bulk soil. The pH decreased in the complete soil column (not only close to the roots) when ammonium nitrogen fertilizer was applied. The microorganisms-induced nitrification decreased the pH in the bulk soil too, by about 0.9 pH unit. These results suggest that more attention should be paid to the chemical changes caused by soil life, to the chemistry of living soils. Nutrient uptake by plant roots depleted the mobile nutrient ions (NH_4^+-N and K^+) from the rhizosphere soil up to about 10 mm.

Decomposition. Several experiments were unsuccessful using the Weende Ecke soil because unknown white fungi attacked the seedlings. The chemical properties of the rhizosphere soil were completely modified in the root environment of fungi attacked plants. Under aerob conditions redox potential decreases were measured, reflecting that reducing processes were operating. The pH did not decrease in the mean time. The nutrient gradients were reversed as well: nutrient excesses were measured instead of nutrient depletions. Nutrient uptake by plant roots turned to nutrient supply from plant roots to their soil environment.

Synthesis or decomposition. The plants were distinguished according to their "life status" as living (or integrating plants: synthesis) and dying (or disintegrating plants: decomposition). The dying plants caused reductive processes in the rhizosphere soil without significant pH changes. Conversely the vital processes of the vigorously growing plants were incident to oxidative processes, which were accompanied with pH-decreases as well. The NH_4^+-N and K^+ ion distributions of the rhizosphere soil also confirmed this distinction. The synthesis was carried out by living plants, which were growing well and depleted the nutrients from the rhizosphere soil. The decomposition occurred in dying plants, when nutrients were released from decomposing plants to the rhizosphere soil (***Figure 3***).

THE QUALITY OF ACTIVATED EM

The concept of EM Technology has opened a new age in soil, agricultural and environmental sciences. This brand new concept cannot be studied in traditional ways. The present methodologies should be revised and new methods should be elaborated. Our researches focus the attention on two significant areas:

- It is very important to characterize the quality of EM products for the sake of quality control. First the quality of activated EM was studied as a function of time.
- It is essential to demonstrate the efficiency of activated EM in different soils.

EM represents a community of microorganisms. The quality of this community can be best characterized during EM activation. Fermentation experiments have been developed to characterize the process of EM activation and the quality of activated EM. In the first experiments technological factors were studied. In the second experiment the process of EM activation was characterized by biological and chemical monitoring.

Technological factors of EM activation

The effect of key technological factors on the activated EM was characterized by fermentation of 24 hours. The effects of aeration, different substrates and concentrations were studied (***Table 3***).

The cell numbers were rare or low when sugar-beet molasses substituted sugarcane molasses. This indicated that EM1 preferred to grow in sugarcane molasses; the other culture media were less efficient. Sugarcane molasses gave high cell numbers while the bacteria/yeasts ratio remained 1/1.

High cell numbers could also be measured in aerated experiments, but then the bacteria/yeasts ratio was pushed toward bacteria. This indicated that aeration favored bacteria growth. This modification of bacteria/yeast ratio is not advantageous taking into account that soil fungi are very sensitive to environmental conditions.

The optimum results could be achieved when the fermentation was carried out under anaerob condition applying 3% EM1 and 3% sugarcane molasses.

Biological and chemical monitoring of EM activation

The activation of EM - that is the growth of microorganisms - was followed as a function of time. Anaerob fermentation was carried out. 3% EM1 and 3% sugarcane molasses were applied. Both the biological and the chemical changes were monitored for 15 days during EM activation. 10 samples were taken at different times. The number of microorganisms characterized the process of fermentation. The quality of activated EM was characterized by measuring biological activities. Microorganisms, like plant roots, modify their environment. The EM induced chemical changes were analyzed in the solution phase as a function of time.

Studying the biological and chemical processes together was expected to contribute not only to the quality control, but also to the eco-engineering fundaments of EM advisory system.

Biological monitoring

The number of microorganisms

The number of different microorganisms was determined by plate count technique. The number of viable bacteria was determined on nutrient agar according to Szegi. Micro-fungi were developed on modified Martin agar. Actynomycetes were counted up on casein – glucose agar according to Jensen.

The number of different microorganisms is demonstrated in ***Figure 4***. During EM activation the number of bacteria and micro-fungi covered more than 5 orders of magnitude, the number of actynomycetes covered more than 3 orders of magnitude. Both the number of bacteria and the number of micro-fungi could reach a higher concentration than 10^9 CFU/ml. The high number of micro-fungi is especially advantageous; taking into account that soil fungi are very sensitive against environmental conditions. These orders of magnitude clearly proved that the applied technology of EM activation is very efficient. The growth of different microorganisms was very intensive demonstrating that the biotic potential of EM1 is very high.

During EM activation the trends of viable numbers were similar for the different microorganisms, indicating that the growth of bacteria, micro-fungi and actynomycetes was also comparable. This meant that the different microorganisms could develop side by side and could reach high concentrations where they did not compete with each other but they were prosperous side by side. In fact ***Figure 4*** demonstrates the co-existence and co-prosperity.

It is also important to notice that the number of microorganisms reached high concentrations on the third days and these concentrations did not change much until the end of the experiment. The constant numbers of viable counts proved the ecological stability of activated EM1.

Studying the number of microorganisms it was concluded that during EM activation the bacteria, micro-fungi and actynomycetes were able to grow side by side and reaching high concentrations their co-existence proved to be stable.

Microbiological activities

Biological monitoring was characterized not only by number of microorganisms but also by their activities. Different EM doses - corresponding to 0, 1, 5, 10 L EM1 per hectare - were applied in a good quality test soil. A

calcareous chernozem soil (Feozem) was used to test the microbiological activities of EM as a function of time.

Dehydrogenase enzyme activity (DHA) characterizes the biological activity of the microbial community. Dehydrogenase enzymes belong to oxido-reductases. Active dehydrogenases are considered to exist as integral parts of intact and living cells. Dehydrogenase activities are thought to reflect the total range of oxidative activities of the microorganisms. The *phosphatase enzyme activity* and *substrate-induced respiration* were also measured. Official standard methods were applied. The overall activity of all microorganisms could be characterized during activity measurement.

The EM concentration determined the level of DHA (***Figure 5***). Higher EM concentrations resulted in higher dehydrogenase activities. The effect of EM concentration was significant. Dehydrogenase activities were fluctuating and the scattering was higher in case of higher concentrations.

There was no clear relation between phosphatase enzyme activities and EM concentrations. The measured phosphatase activities covered a narrow range as a function of EM concentration. This is probably caused by the limited phosphorus-containing substrates; the available phosphor content of sugarcane molasses determined the enzyme activity.

The vitality of the microbial community can be characterized by substrate-induced respiration. Only the intact microorganisms are able to respire, therefore CO_2 production should be related to the quantity of the active biomass. D-glucose was added to EM treated soils and CO_2 production was measured every hour, for 8 hours. The mean values are indicated in ***Figure 6***. The respiration of the untreated test soil was 1- 2 mg CO_2/100 g soil/hour. The substrate-induced CO_2 production was highly increased by the EM treatments. Higher EM concentrations resulted in higher CO_2 productions, corresponding to higher soil vitality.

The quantity of active biomass was estimated using the CO_2 production of the first hour. A very close (R^2 = 0.9752) linear relationship was found between the applied EM concentration and the microbial biomass. The application of 1 L EM1/ha increased the originally active biomass (426 mg C/kg soil) by about 100 mg microbial C/kg soil. At present this relationship is valid only for the test soil, however it should be verified for different soils in the future.

Among microbiological activities the dehydrogenase enzyme activity and substrate-induced CO_2 production proved to be good indicators to characterize the effect of activated EM on soil vitality.

Chemical monitoring

The microbiological processes during EM activation induced chemical changes in the solution phase, which were also monitored.

The pH decreased during EM activation from 4.9 down to 3.6. The pH value was measured in the suspension and also in the equilibrium filtrate. The corresponding pH values correlated with each other, indicating that the acidifying agents were present in soluble form, in the solution phase.

Soil acidification is one of the major soil degradation processes in Europe (especially in Hungary, Poland, and Germany), therefore acidification caused by EM activation was characterized quantitatively too, by titratable acidity. The acid concentrations of the suspension and of the solution phases were identical, confirming that the acidity was present in the solution phase. By the end of EM activation 60 mmol/l acidity was produced. If this were strong acid then the pH would be 1.2. Since the measured pH was 3.6, that meant that weak organic acids should have been produced (lactic acid, acetic acid, etc.).

Fermentation processes under anaerob conditions can create reductive environment in soils. Thus redox potentials were measured and pe values were calculated. During EM activation the redox potential could decrease down to 54 mV then it started to increase again. The quantitative characterization of redox status of soils is not easy at present.

EM activity can consume and also mobilize nutrients. As a consequence of this the chemical composition of the solution phase was measured by ICP. The concentration of macroelements (Ca, Mg, Na, K) did not change significantly. On the other hand the original P concentration (34 mg/L) decreased down to 17 mg/L, what was caused by the P consumption of growing microorganisms. The Mn concentration decreased down to a minimum value then started to increase back again. The Cu concentration decreased continuously, indicating that this element was needed for microbial growth.

The results of chemical monitoring indicated significant changes in the solution phase during EM activation. The pH value decreased very much, what was caused by the organic acid production of EM. The P concentration of solution phase seems to be a good indicator to characterize the growing process of microorganisms.

EFFICIENCY OF ACTIVATED EM IN DIFFERENT SOILS

The biological fundament of soils is modified when soils are treated with a microbial community. EM is a very complex mixture of effective and beneficial microorganisms, which is capable to modify not only the biological, but also the chemical and physical properties of soils. To characterize the effects of a microbial community (EM) on soils represents a new challenge for soil science. The available methods cannot be applied directly, since they have been developed to answer former questions.

Up-to-date soil ecological methods should be elaborated to characterize the presence, stability and effects of EM on soils and plants. In other words eco-engineering fundaments of EM applications should be further developed, which can contribute to a more accurate EM advisory system. Biological indication is needed which characterizes the EM induced biological changes. Both soil microbiological properties and plant characteristics can be applied as bioindicators. In Hungary EM is categorized as phyto-stimulating inoculum, therefore plant was used as bioindicator. White mustard (*Sinapis alba*), what is often applied in official Hungarian standards, was used as test plant.

Effect of EM on germination

The effect of EM on test seeds was studied in a germination experiment of four days. EM1 vitalized the germination, because the average shoot length was increased by 25%. The average root length was not affected by EM treatment.

Efficiency of activated EM in different soils

When soils are treated with activated EM then microorganisms of EM and the indigenous microorganisms of soils are mixed. EM can influence plant growth by enhancing the microbiological activity of the indigenous microflora.

The stimulating effect of EM on plant growth was studied in pot experiments, where the experimental conditions could be fully controlled; therefore the efficiency of activated EM in different soils could be studied in details.

In the pot experiments the applied EM doses; the test plant and the experimental conditions were identical. As a consequence the behavior of different soils could be compared. Five different soil samples were selected, which covered a wide range of soil properties. Three of them represented different forms of soil degradation: the *chernozem soil*: soil acidification + structure degradation, meadow chernozem soil, Karcag; the *saline soil*: soil salinisation + soil compaction, meadow solonetz soil, Karcagpuszta; the *clay soil*: soil compaction + surface crust formation, meadow soil, silty clay, Kisújszállás. The calcareous *sandy soil* and the acidic *organic soil* were represented by Bugyi soil and Florasca B soil, respectively.

The soils were treated with activated EM and rested for more than three weeks. Then white mustard (*Sinapis alba*) were grown on the EM treated soils. The process of germination was monitored. After two weeks the seedlings were characterized in details. The number, height and fresh weight of shoots and the N, P, K, Ca contents of shoots were determined.

The process of germination was not the same in different soils. EM increased the germination in four soils and the results were statistically significant. However, in the sandy soil the germination could not be increased further, due to its originally high germination %.

The number of seedlings at the end of the experiment was used to characterize the biological activity of the soil – plant system. High seedling numbers indicate the vitality of a harmonic soil – plant system. Low seedling numbers reflect some disharmony, caused by any limiting soil ecological conditions.

The number of seedlings was different in the various soils. It was very good (higher than 90%) in the saline soil (Karcagpuszta) and clay soil (Kisújszállás), it was good (above 85%) in the chernozem soil (Karcag). In the organic soil the number of seedlings was low and fluctuating (65 – 87%), probably due to toxic or anti germinating agents. As a consequence of this fluctuation the results in organic soil could not be evaluated properly.

The chernozem soil, the saline soil and the clay soil had a maximum as a function of EM dose. The maximum

value was in the range between 1 – 10 L/ha, indicating that the optimum EM dose was diverse in different soils.

The shoot length characterized the effect of EM in different soils (***Figure 7***). In order to get a reliable average value the length of each shoot was measured. Three soils exhibited nice maximum curves. It deserves attention that the lowest EM dose (corresponding to 1 L EM1 per ha) had a remarkable influence on shoot length, what reflected that few effective microorganisms could produce high contribution to plant growth. The optimum dose was different; its value was between 1 – 10 L/ha, depending on the original soil characteristics.

The optimum dose can be interpreted as follows. If EM dose is lower than the optimum dose then EM cannot take its maximum effect. Applying higher EM dose than the optimum dose may result in that EM has a decreasing positive effect. In case of too high concentrations EM can compete with the plant roots for soil nutrients.

The fresh weight of seedlings was also determined. The fresh weight characterizes the synthesis of plant material; therefore it is considered to be the best indicator to demonstrate the effect of EM. ***Figure 8*** demonstrates that the shoot weight represented different levels. Applying the same experimental conditions various plant productions were achieved in different soils. This is clear evidence that both soil ecological conditions and EM doses determine the plant reaction together.

The effect can be better described if relative % is applied, using the control treatment as a reference value (***Figure 9***). According to the results EM could increase the fresh weight by maximum 31 - 34% in the chernozem-, clayey- and organic soil, and by maximum 13% in the sandy and saline soil. The maximum curves indicated that the optimum EM dose was different in various soils, depending on their original properties. EM advisory system has to take this into consideration the soil ecological conditions.

The nutrient content of seedlings is a measure of nutrient uptake or mobilization.

Most soil inoculators available are capable to fix atmospheric nitrogen; therefore the nitrogen content of plant gives information on nitrogen uptake of plants. EM application increased the nitrogen content of seedlings by different extent. The lowest EM dose (1 L/ha) was capable to increase the nitrogen content by 21%, 9%, 8%, 2% and 0% in the five soils under study (***Figure 10***). These results indicate that EM can contribute to nitrogen uptake by plants under aerob conditions. As high as 10 – 28 % increases could be achieved in various soils applying different EM doses. Further studies are needed to make more precise characterization of EM effect on nitrogen uptake.

The effect of EM on phosphorous mobilization was more homogeneous (***Figure 11***). In mineral soils the P mobilization was very remarkable, it was 29% - 37%. In each mineral soils the maximum effect was detected at 3 L EM1/ha.

On the basis of the pot experiment it was concluded that EM application stimulated the plant growth. The effect of EM had an optimum dose, which was different in various soils. The optimum EM dose was usually between 1 – 10 L/ha, depending on the original soil ecological conditions.

Long-term EM field experiments

Calibration experiment

An EM field experiment has been set up on a meadow chernozem soil (Karcag). The field is situated next to a mineral fertilization experiment, thus EM experimental results and mineral fertilization results can be compared with each other. The nutrient equivalence between EM treatments and NPK treatments will be estimated.

Saline soils

Research of salt-affected soils has long tradition in Hungary. An EM field experiment has been set up on a meadow solonetz soil, where soil salinisation and soil compaction are limiting factors of soil fertility (Karcag puszta). The biological amelioration of a degraded soil is studied in this experiment.

These two long-term field experiments have been started and can be financed this year.

Table 1. Microorganisms in soils of temperate region under average and optimum living condition

	average number of individuals per m^2	optimum number of individuals per m^2	average/ optimum %	average living mass g/m^2	optimum living mass g/m^2	average/ optimum %
MICROFLORA						
bacteria	1.0E+14	1.0E+16	**1.0**	100	700	**14**
actinomycetes	1.0E+13	1.0E+15	**1.0**	100	500	**20**
fungi	1.0E+11	1.0E+14	**0.1**	100	1000	**10**
algea	1.0E+08	1.0E+11	**0.1**	20	150	**13**
SUM	1.1E+14	1.1E+16	**1.0**	320	2350	**14**

Figure 1. Factors that determine the success of any microbial inoculum in soils

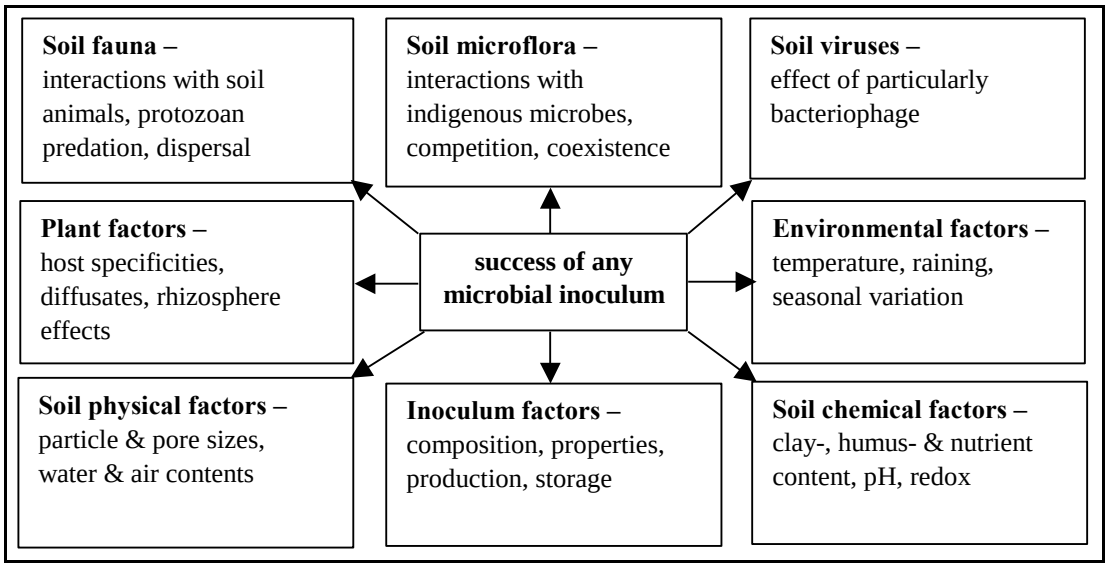

Table 2. Synthesis and entropy in the soil / plant system

Synthesis	**Decomposition**
Entropy decreases	Entropy increases
Ordering processes	Decomposition processes
Processes	**Processes**
Photosynthesis	Respiration
Plant growth	Plant decomposition
Microbial growth	Microbial decomposition
Biochemical synthesis	Biochemical decomposition
Formation of organic matter	Decomposition of organic matter
EM for plant synthesis	EM for waste decomposition
Formation of minerals	Weathering of minerals
Structure development	Structure breakdown
Aggregation	Disaggregation
Flocculation	Dispersion
Characteristics	**Characteristics**
Formation of larger units	Formation of smaller units
Decreasing number of particles	Increasing number of particles
More ordered system	Less ordered system

Figure 2. Acidification in the rhizosphere soil

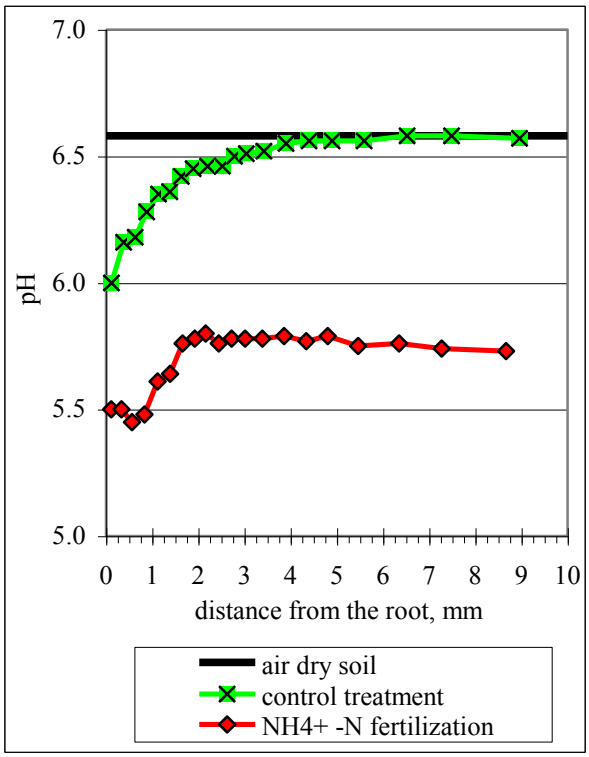

Figure 3. The NH_4^+-N in the rhizosphere soil of growing and dying plant root

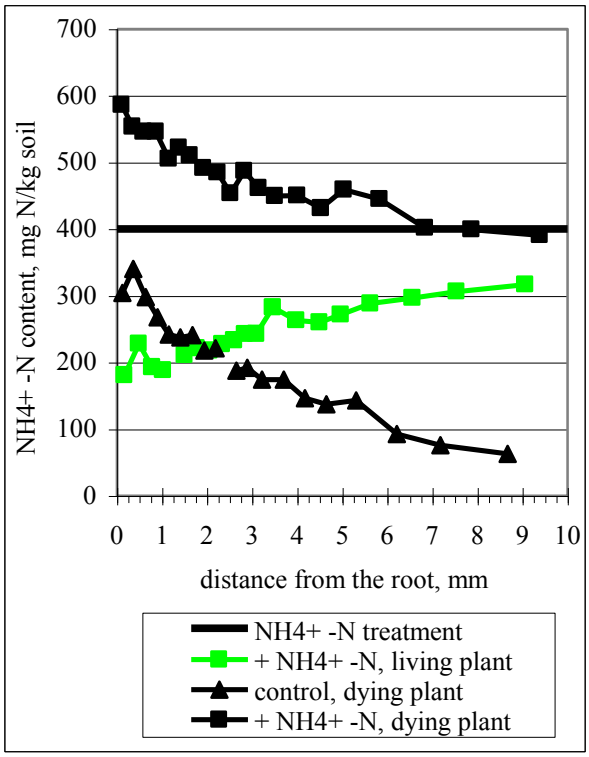

Table 3. The effect of technological parameters on EM activation

aeration	EM1	culture media	culture media	culture media	microscopic picture		cell number
0 - 12 hours	concentration	sugarcane molasses	sugarbeet molasses	isosugar	bacteria	yeasts	CFU/ml
no	3%	3%			50%	50%	5.0E+09
no	3%	2%			50%	50%	1.5E+09
no	2%	3%			50%	50%	1.3E+09
no	2%	2%			50%	50%	1.0E+09
no	1%	3%			50%	50%	4.5E+08
no	2%		1%	2%	rare	rare	3.0E+08
no	3%		1%	2%	rare	rare	2.0E+08
no	2%		1%	2%	50%	50%	1.4E+08
no	3%		3%		rare	rare	1.1E+08
yes	2%	3%			60%	40%	4.5E+09
yes	1%	3%			70%	30%	4.0E+09
yes	3%	3%			60%	40%	2.1E+09
yes	3%	2%			60%	40%	1.3E+09
yes	2%	2%			60%	40%	6.0E+08
yes	3%		3%		rare	rare	2.0E+07
yes	3%		1%	2%	rare	rare	1.0E+07

Figure 4. The number of microorganisms during EM activation

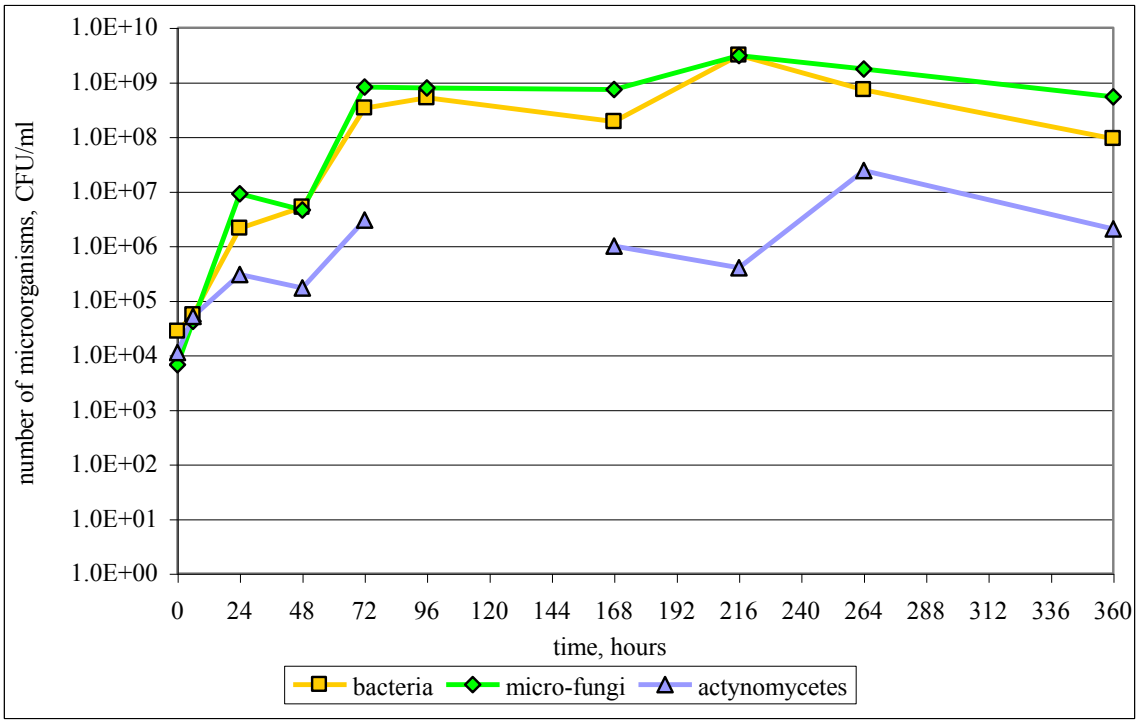

Figure 5. The effect of EM on dehydrogenase enzyme activity

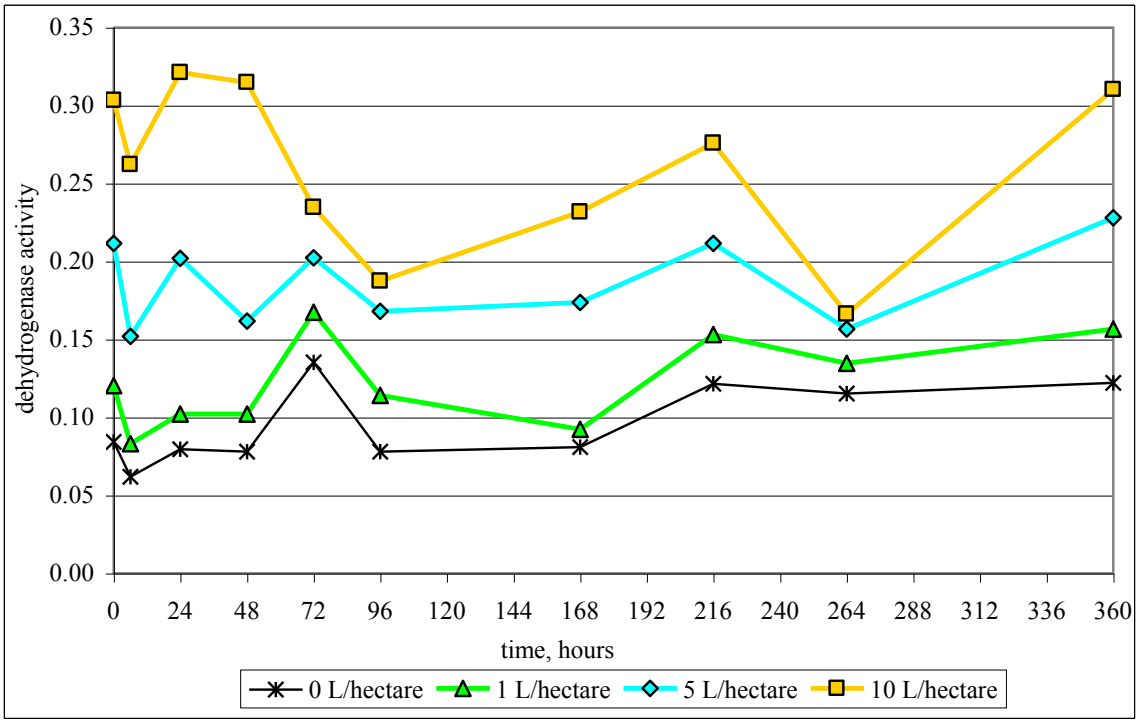

Figure 6. The effect of EM on substrate-induced respiration

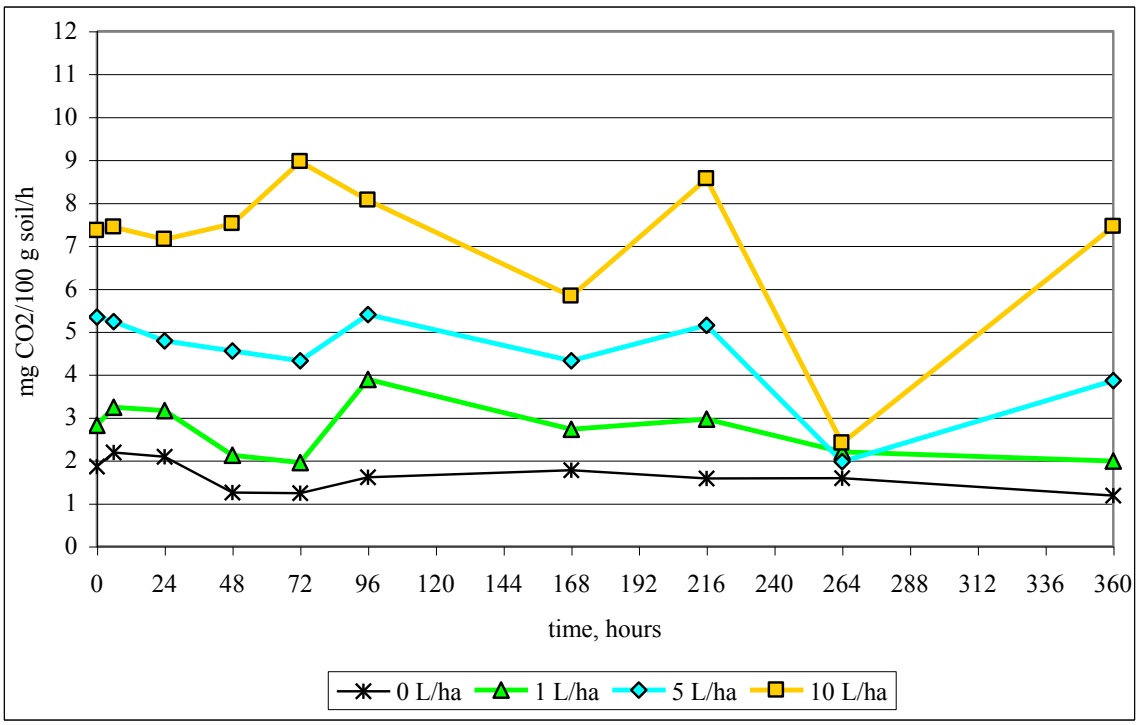

Figure 7. The effect of EM on shoot length of seedlings in different soils

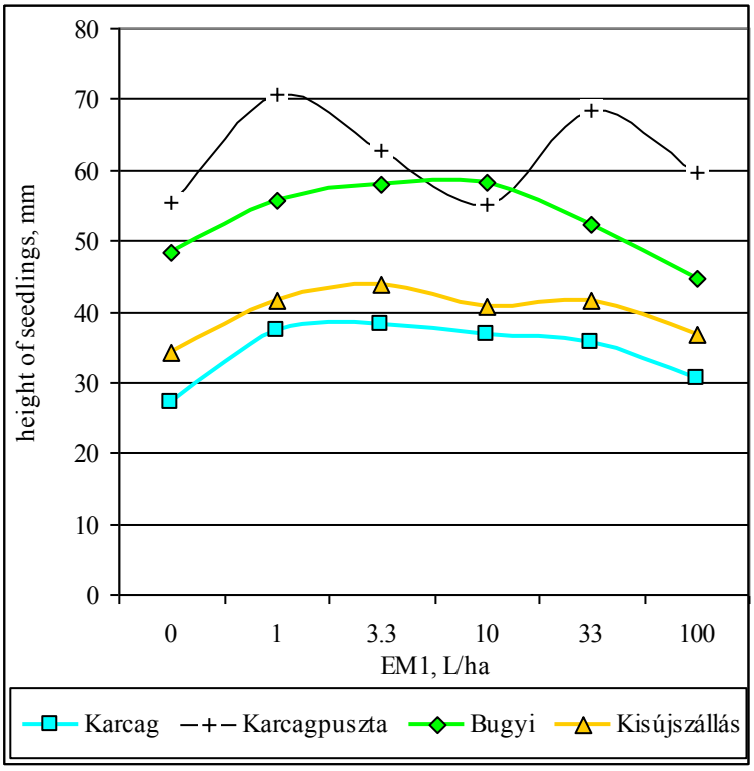

Figure 8. The effect of EM on fresh weight of seedlings in different soils

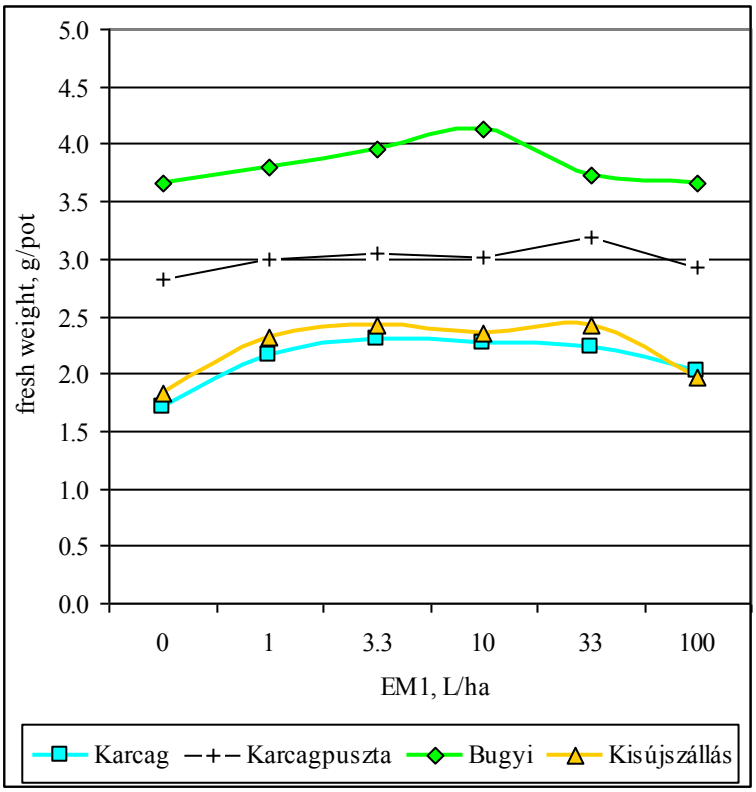

Figure 9. The relative effect EM on fresh weight of seedlings in different soils

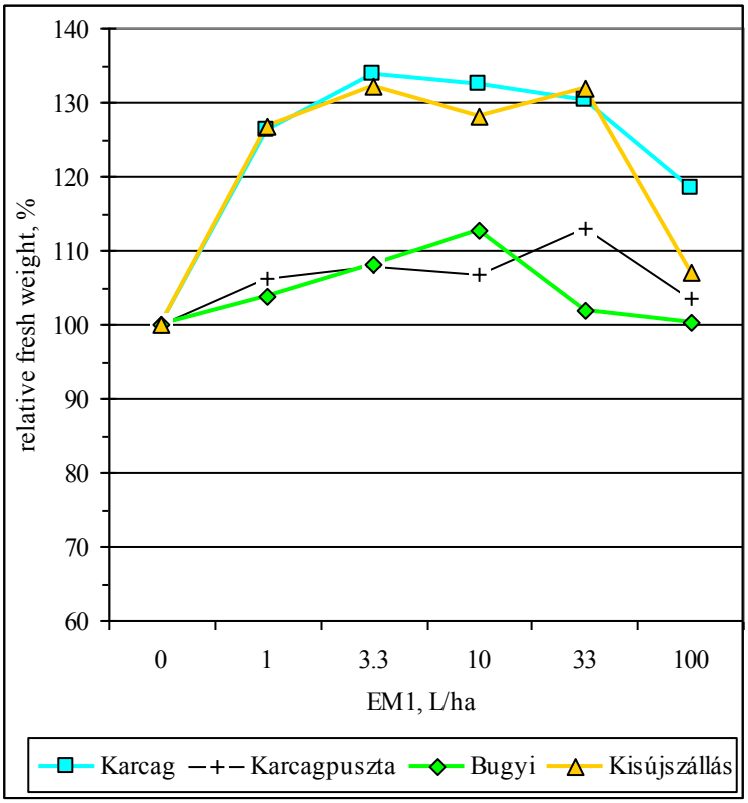

Figure 10. The relative effect EM on nitrogen content of seedlings in different soils

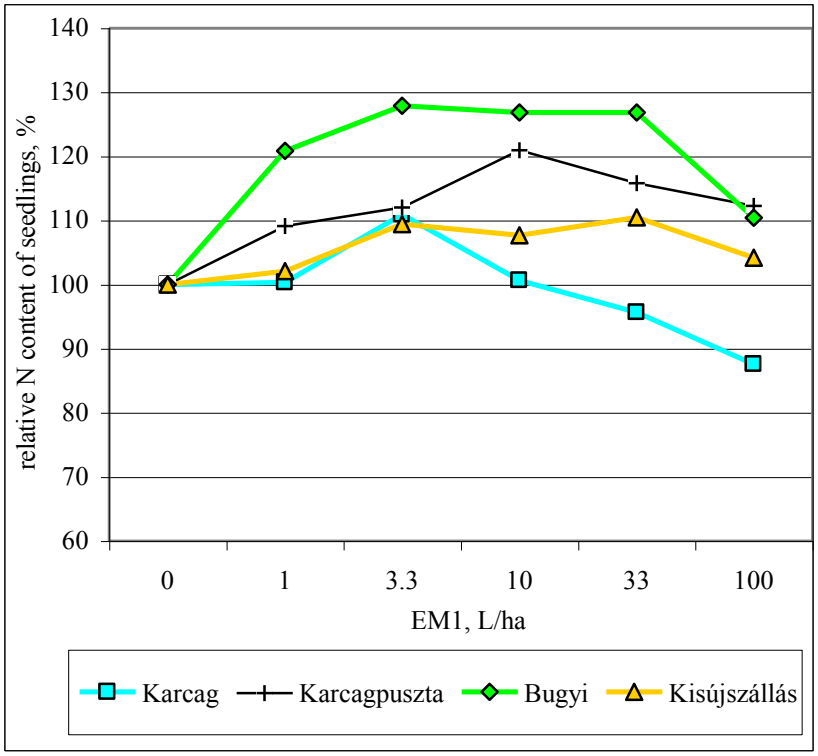

Figure 11. The relative effect EM on phosphorous content of seedlings in different soils