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THE PRINCIPLES OF SUSTAINABLE AGRICULTURAL CULTIVATION AND THE SUPPLY OF NUTRIENTS TO OUR CULTIVATED PLANTS

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SUMMARY

Hungary's edaphic and climatic conditions are excellent for agricultural production, including crop production. Year after year, farmers can boast higher and higher yield averages and, in many cases, better technological quality, which is a fundamental custodian of agriculture's income-generating capacity. However, intensive farming in almost all agricultural areas has led to a physical and chemical deterioration of the soil, which in the long run endangers the structure of soils, the operation of its 3-phase system, the nutrient supply of our cultivated plants, and ultimately successful farming.

Keywords: soil, sustainability, nutrient supply, soil testing

INTRODUCTION AND LITERATURE REVIEW

Hungary's edaphic and climatic conditions are excellent for agricultural production, including crop production. Year after year, farmers can boast higher and higher yield averages and, in many cases, better technological quality, which is a fundamental custodian of agriculture's income-generating capacity. Although modern machines, machine connections, and cultivation technological developments would be able to meet the sustainability needs of tillage and nutrient supply that are maximally adapted to the soil properties, only a few of our farmers use their opportunities. Most people engage in intensive farming that treats the soil and treats the soil as a growing medium. Although this shows a favorable return in the short term, in the medium and long term we have to reckon with the deterioration of soil fertility over millions of years. Intensive farming, therefore, has a serious price:

- the stock of organic matter in our soils and its quality is constantly decreasing as a result of industrial farming,
- their structure, which is the custodian of water, heat and air management, and biological activity of our soils, is deteriorating year by year,
- their ability to extract and supply nutrients, their ability to renew themselves, is weakening.

The deterioration of the renewable capacity of soils, and ultimately their "health", which manifests itself in a decrease in their productivity over time, can now be observed in some form in almost all agricultural areas. Due to the deteriorating structure and the weakening stability of the structural elements of the soil, our soils are less and less able to mitigate the drought periods that occur during climate change. However, due to the reduced stability of the structural elements of the soil, in case of intense rainfall, we have to reckon with water levels and inland water on more and more agricultural plots, which greatly hinders the living conditions of our cultivated plants and can lead to further destruction of our soils (*Kalocsai and Schmidt*, 2003).

We need to recognize that intensive, large-scale farming, as has been the case in the past 60 years or so, cannot be maintained in its current form in the future. We need to understand how our soils work, better understand the biological and ecological interrelationships, and accept that in the long run, we will only be able to meet the food needs of our growing society in harmony with nature.

We need to stop with the "blackmail" farming, which ignores soil properties and ecological contexts and has no scientific physiological basis, and is often based on "habit", the most critical disadvantages of which can be summarized as follows:

- We have virtually no organic matter management,
- Liming is an unknown concept to most of our farmers, although some of our soils would require it
- In most cases, we cannot talk about a harmonious nutrient supply based on soil test results

- In many cases, our supply of nutrients is limited to macroelements (N, P, K), the replacement of microelements takes place "possibly" in plantations,
- We follow the "usual" soil-destroying practice
- The main objective is not the soil health but the performance
- Our farming is characterized by an excessive number of turns, trampling damage, compaction, and cultivation errors
- As a result of improper cultivation, the physical-biological, and chemical properties of the soil as a habitat are reduced, which results in a decrease in the fertility of our soils (*Birkás et al.,* 2002).

No commonly used recipe can be given to make our farming sustainable, and we must be aware that, like all modifications, it takes time. Farmers need to understand that long-term profitable farming can only be done on healthy soils. This requires time, the formation of a professional-scientific approach, and, where appropriate, political recognition. We need to realize that the role of agriculture goes far beyond food production and income generation of the 'agricultural industry'. The farming society has an ecological and nature conservation obligation through the most important and unique resource, the soil capable of continuous renewal because our future is at stake.

A sustainable management system is a complex and dynamic unit covering many sub-areas. An attitude to farming, nature, life that does not require special investment. In many cases, the available infrastructure is ample to "make" our management sustainable.
In general, it is characterized by:

- Energy- and water-saving
- Production structure adapted to local conditions and demand
- Tillage adapted to dry conditions
- An environmentally friendly and harmonious nutrient supply
- Integrated Crop Management
- Modern animal husbandry
- A trained professional who strives for sustainability
- A decision support system that recognizes and takes into account as many ecological contexts as possible

Proper organic matter management, the application of tillage methods aimed at preserving and, in any case, improving the structure of the soil, the supply of reasonably chosen and scientifically based nutrients are all custodians of sustainability. Let us not forget, however, that all of this requires a team of professionals with excellent professional knowledge, who recognize the importance of soil protection, and who are committed and trained. And all of this is inconceivable without education, i.e. continuous professional development.

The determination of the fertilizer requirements of our cultivated plants is based on soil tests, the determination of the uptake (soluble) nutrient content of the soil, the interpretation of the soil test results, and the knowledge of the nutrient requirements of the plants. (*Kalocsai et al.,* 2018)

Based on the results of the soil test, we can continue efficient and environmentally friendly nutrient management, the cost of which is recouped several times over.

DESCRIPTION OF EXPERIMENTS

In this article, we want to help to understand and roughly interpret the "numbers" of soil test results so that the farmer can at least broadly determine the soil characteristics of his areas as well as his ability to provide nutrients by quickly reviewing the test results. At the same time, we draw your attention to the fact that the basis of a truly professional and effective nutrient supply is an accredited laboratory test based on representative soil sampling (MSZ-08-0202-1977) (*Kalocsai*, 2007/A).

In Hungarian soil testing and consulting practice, we generally use 14 test parameters to determine the most important soil characteristics. These are *acidity/basicity (pH), Golden Binding Number (KA), total water-soluble salts (%),* humus content *(%), carbonated lime content (%), AL soluble P_2O_5, K_2O,* and *Na* content (mg/kg); the *contents of nKCl-soluble Mg, NO_2-NO_3-N,* and *SO_4^{2-}-S (mg/kg),* and the contents of *EDTA soluble Cu, Mn,* and Zn *(mg/kg)*. The method and specifications for the determination of the above parameters are described in MSZ-08-0206-2:1978; MSZ-08-0205:1978; Standards MSZ-08-0210-2:1977 and MSZ-20135:1999 are described in detail.

As a result of the laboratory examination of the samples, we receive the soil test result sheet, which therefore contains the following parameters (*Kalocsai*, 2007/B; *Birkás, 2001*).

The approximate value of the results is summarized based on István Buzás (1983), the creator of the Hungarian nutrient supply consulting system:

$pH_{(KCl)}$ - the pH of the soil

pH_{KCl} shows the pH of the soil. Based on the pH_{KCl} results, our soils can be classified into the following pH categories (*Table 1*).

Table 1: Soil pH categories (pH_{KCl})

pH_{KCl}	Category
<4.5	strongly acidic
4.5-5.4	acidic
5.5-6.7	slightly acidic
6.8-7.1	neutral
7.2-7.9	weakly alkaline
8.0<	alkaline

The pH of soils, directly and indirectly, determines the growth and development of plants. Weakly acidic and near-neutral pH is the most optimal for nutrient uptake by plants. Alkaline pH is unfavourable for the uptake of trace elements, while excessively acidic conditions can lead to the dissolution and uptake of toxic amounts of macronutrients and other heavy metals.

Golden Binding (KA) - physical soil type

The Golden Binding is determined by adding distilled water to the air-dry soil with stirring and measuring how many millilitres of water per 100 g of soil is required for it to become a pulp of a defined consistency that gives the report test. The amount of water in ml required to make 100 g of soil that is not yet flowing is equal to the binding number. The dimensionless binding number is most related to the clay content of the soil, so in the case of bound soils, a large number is obtained in the case of high clay content, and a small number in the case of loose sandy soils. *Table 2* shows the relationships between physical soil type, KA, clay content (A%), sludge + clay content (I+A%), 5^h capillary water uplift, and hygroscopicity (hy%).

Table 2: Relationship between physical soil type and soil A%, (I+A)%, KA, 5^h water uplift and hy

Soil tissue, physical soil type	A %	(I+A) %	KA	5^hmm	hy %
Coarse sand (dh)	<5	<10	<25	350<	0-0.5
Sand (h)	5-15	10-25	25-30	350-300	0,5-1
Sandy loam (hv)	15-20	25-30	30-37	250-300	1.2
Adobe (v)	20-30	30-60	37-42	150-250	2-3.5
Clay loam (av)	30-40	60-70	42-50	75-150	3.5-5
Clay (a)	40-45	70-80	50-60	40-75	5-6
Heavy clay (na)	45<	80<	60<	40>	6<

% of total salt

The sum of the water-soluble salts in the soil is called the total salt content of the soil. This measurement does not provide information on what salts are present in the soil. It's important to know that, especially in saline soils, because too much salt is one of the causes of poor fertility. The soil is said to be low in salinity if the amount of salts is less than 0.05%, weakly salinic 0.05-0.15%, and salinic 0.15-0.4%. Above 0.4% the soil is heavily salinic.

Percentage of humus is the humus content

The humus content is used to characterize the organic matter content of the soils. Its definition is based on the oxidizability (caramelisation) of organic matter.

The humus content of domestic soils is most often between 0.5 and 6%. However, humus supply should never be judged independently of the physical composition or genetic type of the soil. For sandy soil, 2% is generally considered a good value, but for bound meadow soil, it equals very lean soil. Based on the humus content, the long-term nitrogen supply capacity of the soils is determined. The limits for the humus content are given in *Table 3*.

Table 3: Limits for soil humus content for the assessment of nitrogen supply (*MÉM-NAK*)

Field production area	***K_A***	***humus %***				
		Very poor	***Poor***	***Satisfactory***	***Good***	***Really good***
I. Chernozem soils	>42	<2.00	2.01-2.40	2.41-3.00	3.01-4.00	4.00<
	<42	<1.50	1.51-1.90	1.91-2.50	2.51-3.50	3.50<
II. Brown forest soils	>38	<1.50	1.51-1.90	1.91-2.50	2.51-3.50	3.50<
	<38	<1.20	1.21-1.50	1.51-2.00	2.01-3.00	3.00<
III. Bound meadow and gloomy forest soils	>50	<2.00	2.01-2.50	2.51-3.30	3.31-4.50	4.50<
	<50	<1.60	1.61-2.00	2.01-2.80	2.81-4.00	4.00<
IV. Sandy and loose soils	30-38	<0.70	0.71-1.00	1.01-1.50	1.51-2.50	2.50<
	<30	<0.40	0.41-0.70	0.71-1.20	1.21-2.00	2.00<
V. Saline soils	>50	<1.80	1.81-2.30	2.31-3.10	3.11-4.00	4.00<
	<50	<1.40	1.41-1.80	1.81-2.60	2.61-3.50	3.50<
VI. Shallow topsoil or heavily eroded sloping soils	>42	<1.30	1.31-1.70	1.71-2.40	2.41-3.30	3.30<
	<42	<0.80	0.81-1.21	1.21-1.90	1.91-2.80	2.80<

$CaCO_3$% - the carbonated lime content

Characteristic of the lime content of the soil. Hydrochloric acid was determined by adding hydrochloric acid to the soil and measuring the amount of CO*2* formed with all the carbonates in the soil using a gas burette (Scheibler's calcimeter). From this, we determine by counting how much $CaCO_3$ is equivalent. Based on the carbonated lime content of the soil, the following categories are distinguished (*Table 4*):

Table 4: Limits for carbonated lime content of the soil

$CaCO_3$ %	Category
0	Lime deficient
0.1-4.9	Weakly calcareous
5.0-19.9	Moderately calcareous
20-	Strongly (excessively) calcareous

In addition to the physiological aspects of the plant, lime favorably modifies the structure of the soils, and the stability of the structural elements of the soil. Through the structure of the soil, the appropriate state of lime has a positive effect on the water, heat, and air management of the soils, as well as to the microbiological processes that are essential for the exploration of nutrients. The carbonated lime content of the soils fundamentally affects their pH, and thus the uptake of various nutrients.

AL-soluble P_2O_5 and K_2O mg/kg - the soluble phosphorus and potassium content

Indicates the amount of different phosphorus and potassium compounds that can be extracted from the soil with AL (Ammonium Lactate) solution, expressed as P_2O_5 and K_2O respectively.

Of the total phosphorus and potassium content of our soils, plants are only able to utilize the phosphorus and potassium they can easily access and absorb. We have been using the AL (Ammonium Lactate) method to estimate this content available to plants in Hungary since the 1960s. During the planning of the nutrient supply, the phosphorus and potassium contents of the soil determined according to this method are compared with the specific P_2O_5 and K_2O requirements of the plant to be grown and the specific fertilizer requirement of the plant is determined. Limits for AL-soluble phosphorus and potassium in soils are shown in *Tables 5 and 6*.

Table 5: Limits of soil AL-soluble phosphorus content for the assessment of phosphorus supply (*MÉM-NAK*)

Field production area	***Carbonation $CaCO_3$ %***	***AL-P_2O_5 %***				
		Very poor	***Poor***	***Satisfactory***	***Good***	***Really good***
I. Chernozem soils	>1	50	51-90	91-150	151-250	251-450
	<1	40	41-80	81-130	131-200	201-401
II. Brown forest soils	>1	40	41-70	71-120	121-200	201-400
	<1	30	31-60	61-100	101-160	161-360
III. Bound meadow and gloomy forest soils	>1	40	41-70	71-110	111-180	181-380
	<1	30	31-60	61-100	101-150	151-350
IV. Sandy and loose soils	>1	50	51-80	81-130	131-250	251-450
	<1	30	31-60	61-100	101-200	201-400
V. Saline soils	>1	40	41-70	71-120	121-180	181-380
	<1	30	31-60	61-100	101-140	141-340
VI. Shallow topsoil or heavily eroded sloping soils	>1	50	51-80	81-130	131-200	201-400
	<1	30	31-60	61-100	101-150	151-350

Table 6: Limits of soil AL-soluble phosphorus content for the assessment of phosphorus supply (*MÉM-NAK*)

Field production area	***Gold Binding (K_A)***	***AL-K_2O %***				
		Very poor	***Poor***	***Satisfactory***	***Good***	***Really good***
I. Chernozem soils	>42	100	101-160	161-240	241-350	351-550
	<42	80	81-130	131-200	201-300	301-500
II. Brown forest soils	>38	90	91-140	141-210	211-300	301-500
	<38	60	61-100	101-160	161-250	251-450
III. Bound meadow and gloomy forest soils	>50	150	151-250	251-380	381-500	501-700
	<50	120	121-200	301-330	331-450	451-650
IV. Sandy and loose soils	30-38	90	91-120	121-160	161-220	221-420
	<30	50	51-88	81-120	121-180	181-380
V. Saline soils	>50	200	201-280	281-400	401-550	551-750
	<50	150	151-230	231-330	331-450	451-650
VI. Shallow topsoil or heavily eroded sloping soils	>42	120	121-160	161-220	221-300	301-500
	<42	80	81-120	121-180	181-250	251-450

It should be noted, however, that today's "long-term sustainable, environmentally friendly fertilization systems" (*such as the 3RP System and MTA-TAKI – MTA-GKI*) have lower soil nutrient limits. Overall, regardless of the cultivated plant and soil type, it can be stated that the AL-soluble K_2O content of the soils is **180-200 mg/kg**, and the AL-soluble P_2O_5 content of **150-160 mg/kg** can be considered good.

AL-soluble Na mg/kg - the soluble Na content

Indicates the amount of Na compounds that can be extracted from the soil with the AL solution in Na mg/kg. Excessive Na contents are unfavourable for our cultivated plants and indicate salinization processes. As a general guideline, an AL-Na content of up to 30 mg/kg is acceptable. Values between 40 and 60 mg/kg may indicate certain undesirable processes. In non-saline areas, it is advisable to reconsider and review our irrigation technology, test the irrigation water, and review our nutrient supply technology (e.g., many years of excessive vinasse application). AL-Na contents above 60 mg/kg already indicate unfavourable salinization and salinity.

nKCl-soluble Mg mg/kg - the soluble Mg content

Represents the amount of magnesium compounds that can be extracted with 1 M KCl in elemental magnesium. The assessment of the magnesium supply of the soils is shown in *Table 7*.

Table 7: Assessment of Mg supply (*Buzás, 1983*)

Restriction (K_A)	Mg mg/kg		
	Poor	Satisfactory	Good
<30 (sandy soils)	<40	40-60	60<
30-43 (sandy loam, loam soils)	<60	60-100	100<
>43 (clay loam, clay soils)	<100	100-200	200<

On soils with strong calcareous or high doses of liming, the appearance of possible magnesium deficiency must be taken into account. The deficiency is further exacerbated by high-dose nitrogen, phosphorus, and potassium fertilization, so we supply nutrients with particular care in such areas! In our areas, strive to establish and maintain the Ca:Mg = 6 and K:Mg = 0.5 ion ratios.

nKCl-soluble $NO_2 + NO_3$ - N and SO_4^{2}-S mg/kg - soluble nitrite and nitrate nitrogen and sulfate sulfur

In short, we simply call it nitrate content or sulfate content. It is equal to the amount of nitrogen in the form of NO_3 ion and the amount of sulfur in the form of SO_4^{2} ion which can be extracted from the soil with a 1 M KCl solution.

Although this is the only series of soil studies to demonstrate the effect of N fertilization on soil N-supplying capacity, its role in expert advisory practice is debatable.

EDTA-soluble Cu, Mn, Zn, (Fe) mg/kg - soluble Cu, Mn, and Zn content

Trace elements, including copper, manganese, and zinc, are present in small amounts in the plant (*0.01% to 0.00001%*). Despite their small quantities, their role in plant life processes is essential. In their absence, the yield loss can exceed 40%.

Represents the amount that can be dissolved from the soil with a solution of EDTA (ethylenediaminetetraacetic acid) and 0.1 M KCl. The definition of iron usually does not make sense because its uptake depends on many factors, so the extractable Fe is not proportional to the amount of iron that the plant can utilize. This, as well as the uptake of Mo and B, is easier to infer from plant studies. The limit values for EDTA-Cu and EDTA-Zn in the soils are shown *in Tables 8, 9, and 10*.

Table 8: Estimation of soil EDTA-soluble Cu supply (mg/kg) *(Buzás, 1983)*

Restriction (K_A)	***Satisfactory Cu supply (mg/kg)***		
	Humus %		
	<1	1-3	3<
<30	**0.2 -**	**0.3 -**	**0.6 -**
30-42	**0.3 -**	**0.6 -**	**1.4 -**
>42	**0.6 -**	**1.2 -**	**3.2 -**

Table 9: Estimation of soil EDTA-soluble Zn supply (mg/kg) *(Buzás, 1983)*

Restriction (K_A)	**Satisfactory Cu supply (mg/kg)**		
	pH_{KCl}		
	<6	**6-8**	**8<**
<37 (sand)	26 -	7 -	3 -
37-50 (adobe)	52 -	13 -	4 -
>50 (clay)	118 -	30 -	7 -

Table 10: Estimation of soil EDTA-soluble Zn supply (mg/kg) *(Buzás, 1983)*

Restriction (K_A)	**Zn (mg/kg)**	
	poor	**good**
<38 (sand)	<1.0	1.0 <
38-50 (adobe)	<2.5	2.5<
>50 (clay)	<3.5	3.5<

A FENNTARTHATÓ MEZŐGAZDASÁGI MŰVELÉS ALAPELVEI ÉS TERMESZTETT NÖVÉNYEINK TÁPELEMELLÁTÁSA

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ÖSSZEFOGLALÁS

Magyarország edafikus és klimatikus adottságai kiválóak a mezőgazdasági termelés, ezen belül a növénytermesztés számára. A mezőgazdasági termelők évről évre egyre magasabb termésátlagokkal és számos esetben jobb technológiai minőséggel büszkélkedhetnek, ami alapvető letéteményese a mezőgazdaság jövedelemtermelő képességének. Az intenzív gazdálkodás azonban szinte minden mezőgazdasági területen a talaj fizikai és kémiai romlását vonta maga után, mely hosszú távon veszélyezteti a talajok szerkezetességét, 3 fázisú rendszerének működését, termesztett növényeink tápanyagellátását, végső soron az eredményes gazdálkodást.

Kulcsszavak: talaj, fenntarthatóság, tápanyagellátás, talajvizsgálat

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