STRUCTURE OF THE ENVIRONMENT-FRIENDLY CROP NUTRITION RECOMMENDATION SYSTEM ELABORATED BY RISSAC AND ARI HAS

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Like previous fertilisation recommendation systems elaborated in Hungary, this new system is based on the balance method. The aim of the "A" (minimum) and "B" (environment-friendly) levels is to ensure the achievement of maximum economic yield (approx. 0.95× maximum yield) by creating or maintaining a moderate level of PK supplies. The system also takes into consideration the fact that the financial status of farms where the land has poor or very poor PK supplies is generally far worse than average. In terms of N supplies, the system attempts to satisfy N requirements as accurately as possible.

The "C" (balance-based) and "D" (integrated) levels aim to achieve maximum yields through moderately intensive fertilisation. These variants are based on the same basic principles, but acknowledge the fact that there will always be better situated farms where the aim is to reach maximum yields and where they can afford to apply higher fertiliser rates than are absolutely necessary. These levels are recommended for seed production and for the cultivation of high quality wheat, but should only be applied on land that is not classified as especially sensitive from the environmental point of view.

The N, P_2O_5 and K_2O fertiliser active agent quantities recommended per hectare (x) are calculated by the program using the following equation:

$$x = (Y \cdot S_y \cdot f) \pm C$$

where Y is the planned yield level, t/ha,

S_y is the specific nutrient requirements for the planned yield level,

f is a factor based on the nutrient supply category of the soil, and

C is a correction factor.

1. Planned yield levels

The principle on which the system is based will be presented using the potassium recommendations for five field crops, winter wheat, maize, sunflower, alfalfa and sugar beet, as an example. The system distinguishes between the following yield levels for the five crops in terms of specific nutrient contents (Table 1):

Table 1. Planned yield levels distinguished in the environment-friendly recommendation system on the basis of specific nutrient contents for five major crops

Crop	Average	Lowest	Highest
		yield level, t/ha	
Winter wheat	3.51–4.50	<2.50	>7.50
Maize	5.51–6.50	<3.50	>8.50
Sunflower	1.51–2.00	<1.00	>3.50
Alfalfa (hay, total over 3 years)	14.1–21.0	<7.00	>42.0
Sugar beet	30.1–35.0	<20.0	>50.0

2. Specific crop nutrient contents

One novel component in the environment-friendly fertilisation recommendation system is the fact that the specific nutrient content of the plants is not a constant, but changes as a function of the planned yield level. This is necessary due to the nutrient dilution effect well known in agricultural chemistry.

In long-term fertilisation experiments carried out in Martonvásár (Árendás, 1998) it was demonstrated that the specific nutrient content of plants varies with the year, and thus as a function of the yield level. There was found to be an inverse ratio between the yield level and the specific nutrient content: lower yield levels (dry years) were associated with higher specific contents, and higher yields with lower specific K contents (Fig. 1).

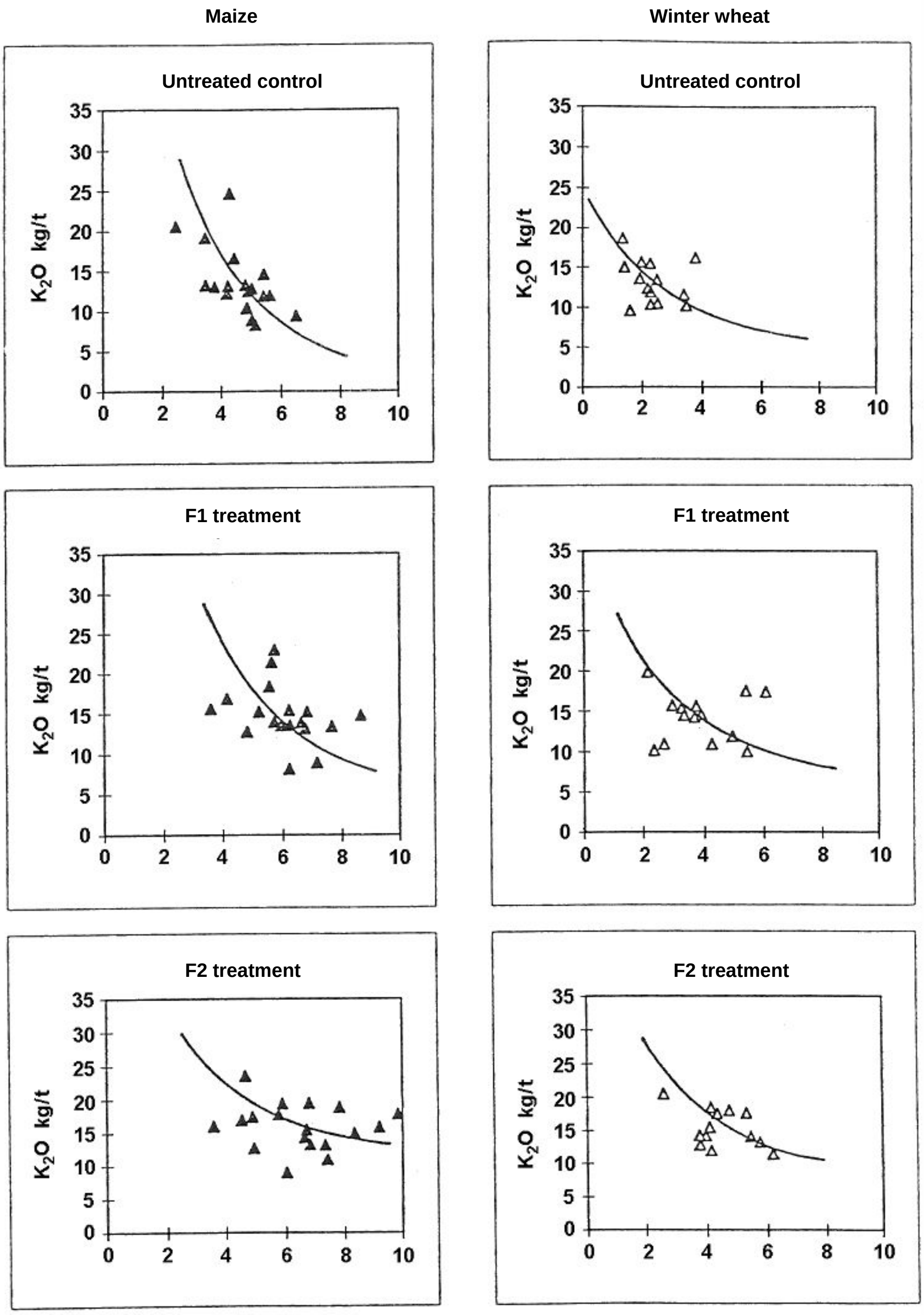

Fig. 1. Changes in the specific nutrient contents of maize and winter wheat as a function of year, fertiliser level (F1, F2) and yield level on chernozem soil with forest residues in Martonvásár (Árendás, 1998)

If a constant specific nutrient content is applied regardless of the planned yield level, there is the danger that the real fertiliser requirements will be underestimated when planning for low yields and overestimated in the case of high yields. This distortion can be avoided by using separate specific nutrient contents for each planned yield level. The specific contents generally accepted for crops in Hungary were applied for the moderate yield level.

Using potassium fertiliser as the example, the specific K contents calculated for various yield levels are presented in Table 2.

Table 2. Specific K_2O contents applied in the environment-friendly fertiliser recommendation system for five major field crops as a function of the planned yield level

Crop	Specific K_2O content, kg/t		
	Average	Lowest	Highest
		yield level	
Winter wheat	17	21	12
Maize	16	20	11
Sunflower	65	75	51
Alfalfa (hay)	18	28	10
Sugar beet	4.4	5.6	3.6

In the light of more recent research (Debreczeni and Debreczeni, 1994) the “average” specific contents associated with a moderate planned yield are generally lower than those applied in recommendation systems elaborated during the period when high rates of fertiliser were the norm.

3. Limit values for soil nutrient supplies

Field fertilisation experiments can be regarded as model experiments with known parameters. The correlations obtained in field experiments are adapted for use in practice with the help of soil and plant analysis. The methods used for soil and plant analysis are calibrated using data from a large number of field experiments set up at locations representative of the varying soil and weather conditions in the country.

Calibration experiments need to be repeated over several years to eliminate the year effect. An example is given in Figure 2, which represents the relationship between the AL-P_2O_5 content of the soil and the grain yield of winter wheat on a calcareous (5% $CaCO_3$) chernozem soil with light loam texture.

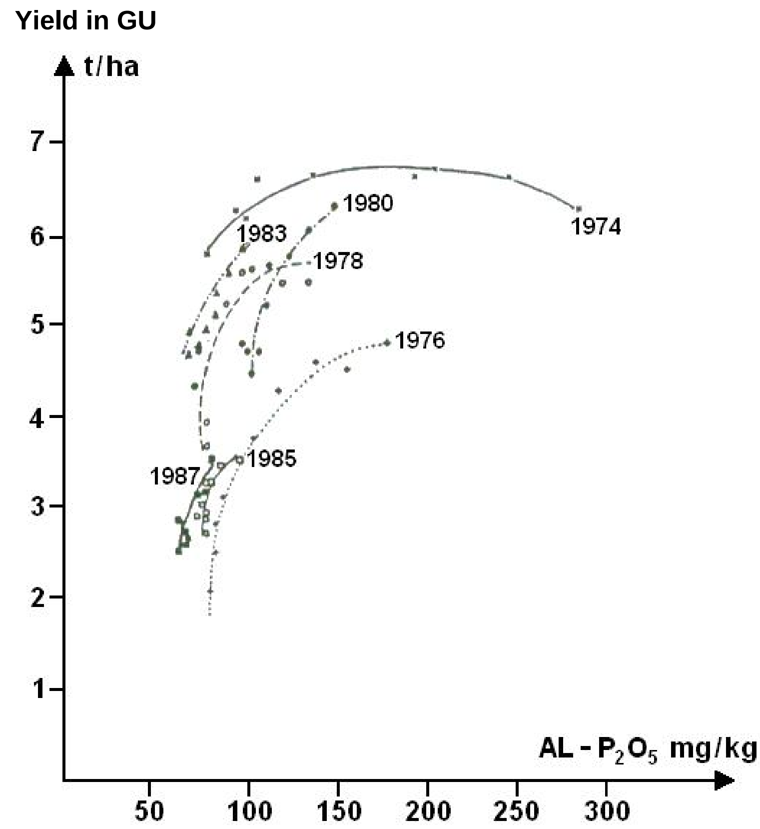

Figure 2. Correlations between the AL-P_2O_5 content of the soil and the grain yield of winter wheat on a calcareous (5% $CaCO_3$) chernozem soil with light loam texture in Nagyhörcsök (Csathó, 1985)

It is clear from Figure 2 that the grain yield of winter wheat follows a saturation curve and in most years increases up to an AL-P_2O_5 content of 150 mg/kg. It can thus be said that on this calcareous soil the lower limit of "good" P supplies, i.e. the AL-P_2O_5 content at which P effects disappear, can be characterised by a value of 150 mg/kg AL-P_2O_5. The yield curve rises steeply up to a value of 100 mg/g (poor supplies), and more gently from 100 to 150 mg/kg (moderate supplies).

As the AL method is extremely dependent on the lime status, the supply categories need to be characterised using different AL-P values on acidic soils. The results of calibration experiments set up on acidic soils indicated that on these soils the P supplies can be regarded as "good" at an AL-P_2O_5 level of 100 mg/kg.

The relationship between soil nutrient supplies and yield was first described by Mitscherlich in the early 1900s using a saturation fuction: $Y = A(1–e^{-c(x+b)})$, where Y is the yield (t/ha), A the maximum yield estimated by the model, c the Mitscherlich slope coefficient, x the quantity of fertiliser active agent applied (kg/ha) and b the quantity of nutrients supplied by the soil (kg/ha). The value of b was estimated by extrapolation.

Mitscherlich's ideas were further developed by Bray (1944). While Mitscherlich calculated correlations for a given soil, Bray expanded the correlation to a series of experiments (modified Mitscherlich–Bray function).

Bray's function can be written as $Y' = 100(1-100^{-cx})$, which represents the correlation between the readily available nutrient content of the control plot (x) and the nutrient effect expressed in terms of relative yields (Y'). Using the potassium experiments as an example, Y' is the K effect expressed as the yield in the NP treatment divided by the yield in the NPK treatment, i.e. the percentage of the total yield that could be achieved without K on a soil with "x" AL-K_2O content. The value of the constant, c, may differ from one crop or nutrient to the other.

The database compiled by P. Csathó at RISSAC, which contains the results of 1–10-year long-term N, P and K fertilisation experiments carried out in Hungary over the last four decades, is an excellent basis for the application and adaptation of the Bray–Mitscherlich approach under Hungarian conditions (Bray, 1944; Csathó, 1997, 2002, 2003). By evaluating the correlations revealed using this database, far more accurate limit values can be determined for soil nutrient supply categories.

In addition, it became possible to make a more precise estimate of the influence of soil texture and humus content on N effects, that of texture and pH (lime status) on the P effects, and of soil texture on K effects.

The limit values established by the new system for soil nutrient supply categories also change as a function of the type of crop. Cereals, for instance, have a much higher P requirement than hoed crops, while the latter exhibit far more pronounced K effects than cereals. The diverse K requirements of winter wheat, alfalfa and maize are clearly illustrated by the database of Hungarian field experiments on K fertilisation.

Based on the correlations outlined above, all the crops were divided into groups, depending on whether they had higher or lower requirements for the given nutrient, judging by the magnitude of the fertiliser response for the nutrient in question. The groupings for the five most important field crops are presented in Table 3.

Table 3. Grouping of the five major crops according to their N, P and K requirements in the environment-friendly fertilisation recommendation system (1: high requirement for the given nutrient; 2: low requirement for the given nutrient)

Crop		Nutrient	
	Nitrogen	Phosphorus	Potassium
Winter wheat	1	1	2
Maize	1	2	1
Sunflower	1	2	1
Alfalfa	2	1	1
Sugar beet	1	1	1

4. Factor dependent on the soil nutrient supply category

The example of potassium will again be used to demonstrate changes in the factor dependent on soil nutrient supply categories in variants "A" (minimum level), "B" (environment-friendly level), "C" (balance-based level) and "D" (integrated level). The four variants in the environment-friendly fertiliser recommendation system only differ from each other for this factor, which results in differences in the fertiliser doses recommended.

The factors applied for fields with poor, medium and good potassium supplies are presented in Tables 4–7 for the A, B, C and D levels, respectively.

Variant "A" only recommends PK fertiliser if PK effects are to be expected, i.e. on soils with moderate or poor PK supplies. The factors used for areas with poor or very poor supplies are lower than those applied by systems that promote the intensive application of fertiliser. Consequently, the replenishment of PK reserves will take longer using the new system.

Table 4. Factors applied for the five main crops when calculating fertiliser doses in variant "A" (minimum level) on soils with poor, medium and good potassium supplies

Crop	Factor depending on K supplies in the case of		
	poor	medium	good
	supplies of potassium		
Winter wheat	0.8	0.6	0
Maize (crop rotation)	1.1	1.0	0
Sunflower	0.5	0.4	0
Alfalfa	0.6	0.5	0
Sugar beet	0.9	0.8	0

Table 5. Factors applied for the five main crops when calculating fertiliser doses in variant "B" (environment-friendly level) on soils with poor, medium and good potassium supplies

Crop	Factor depending on K supplies in the case of		
	poor	medium	good
	supplies of potassium		
Winter wheat	0.9	0.7	0.25
Maize (crop rotation)	1.3	1.1	0.5
Sunflower	0.6	0.5	0.2
Alfalfa	0.8	0.7	0.3
Sugar beet	1.0	0.9	0.3

Variant "B" recommends low rates of PK fertilisation for soils with good PK supplies, and variants "C" and "D" even for those with very good supplies. In contrast to the intensive system elaborated by the Centre for Plant Protection and Agricultural Chemistry of the Ministry of Agriculture and Food (MÉM NAK 19979), none of the variants recommends PK fertilisation in the case of excessive supply levels.

Table 6. Factors applied for the five main crops when calculating fertiliser doses in variant "C" (balance-based level) for soils with poor, medium and good potassium supplies

Crop	Factor depending on K supplies in the case of		
	poor	medium	good
	supplies of potassium		
Winter wheat	1.0	0.8	0.5
Maize (crop rotation)	1.4	1.2	1.0
Sunflower	0.7	0.6	0.4
Alfalfa	1.0	0.9	0.6
Sugar beet	1.2	1.1	0.7

Table 7. Factors applied for the five main crops when calculating fertiliser doses in variant "D" (integrated level) for soils with poor, medium and good potassium supplies

Crop	Factor depending on K supplies in the case of		
	poor	medium	good
	supplies of potassium		
Winter wheat	1.1	0.9	0.75
Maize (crop rotation)	1.7	1.6	1.4
Sunflower	0.8	0.7	0.6
Alfalfa	1.2	1.1	0.9
Sugar beet	1.3	1.2	1.1

5. Consideration of other factors influencing fertiliser requirements (manuring, incorporation of forecrop residues, etc.)

As mentioned above, the N, P and K fertiliser active agent quantities recommended per hectare (x) were calculated using the following equation:

$$x = (Y \cdot S_y \cdot f) \pm C$$

where Y is the planned yield level, t/ha,

S_y is the specific nutrient requirements for the planned yield level,

f is a factor based on the nutrient supply category of the soil, and

C is a correction factor.

The first step is thus to determine the planned yield level for each field and the second step to look up the specific nutrient contents required for the desired yield level in the table. In the third step the table of soil analytical data is used to decide whether the area has very poor, poor, medium, good, very good or excessive supplies of N, P and K based on the given limit values. The fourth step is to calculate the recommended N, P and K fertiliser active agent quantities using the above equation, while the fifth step involves a consideration of factors that modify the mineral fertiliser requirements (previous application of organic fertilisers, incorporation of forecrop residues, etc.). Corrections for these factors are carried out as follows:

5.1. Modifying effect of organic fertilisers: Farmyard manure (FYM)

The macroelement content of FYM depends on the animal species, how the animals were kept and fed, how the manure was treated, etc., so it may vary over a fairly wide range. If analytical results are not available, the following theoretical active agent quantities can be assumed after the spreading and immediate incorporation of 10 t FYM (Table 8):

Table 8. Mean nutrient content (kg/10 t) of mature farmyard manure (FYM) with good or medium quality (Árendás 1995)

FYM quality	N	P_2O_5	K_2O
		kg/10 t	
Poor*	40	20	40
Medium**	60	30	60
Good***	80	40	80

*Originating from animals fed mostly on roughage, with poor manure treatment

**Originating from animals fed mostly on roughage, with correct manure treatment

***Originating from animals fed intensively, mostly on grain feed, with correct manure treatment

The mean mineral fertiliser equivalent of FYM is: N: 0.6, P: 1.0, K: 1.0. On the basis of the above, if mature, litter-containing FYM with medium to good quality is incorporated into the soil, the mineral fertiliser NPK requirements can be reduced as follows, taking soil texture into consideration (Tables 9 and 10):

Table 9. Mean nutrient-supplying ability of FYM on sandy and sandy loam ($K_A \leq 36$) soils (Árendás 1995)

Long-term effect	N			P_2O_5			K_2O		
				kg/10 t					
				FYM quality:					
	poor	medium	good	poor	medium	good	poor	medium	good
Year 1	12	15	20	10	15	20	20	30	40
Year 2	8	15	20	7	10	15	15	20	25
Year 3	4	6	8	3	5	5	5	10	15
Total	24	36	48	20	30	40	40	60	80

Table 10. Mean nutrient-supplying ability of FYM on loam, clay and loam ($K_A \geq 36$) soils (Árendás 1995)

Long-term effect	N			P_2O_5			K_2O		
				kg/10 t					
				FYM quality:					
	poor	medium	good	poor	medium	good	poor	medium	good
Year 1	10	14	18	8	10	15	15	20	30
Year 2	8	11	14	6	10	11	10	18	25
Year 3	6	7	9	3	5	7	8	12	15
Year 4	0	4	7	3	5	7	7	10	10
Total	24	36	48	20	30	40	40	60	80

If exact data are available on the nutrient content of the incorporated FYM, the ratios presented in Tables 9 and 10 can be used, with the same mineral fertiliser equivalence factors (0.6-1.0-1.0) to determine the nutrient-supplying ability for each year.

5.2. Modifying effect of organic fertilisers: Farm slurry (liquid manure)

As the composition of farm slurry depends on a combination of many factors (animal species, feeding, manure treatment, storage, etc.), the following mean values per m³ can be used for the calculations, assuming a slurry:water dilution ratio of 1:1 or 1:3 (Table 11):

Table 11. Mean nutrient content of farm slurry (Árendás 1995)

Type of slurry	N	P_2O_5	K_2O
		kg/m³	
Thick (1:1)	2.4	0.9	2.4
Thin (1:3)	0.8	0.3	0.8

Farm slurry has a mean mineral fertiliser equivalent of N: 0.5, P: 1.0, K: 1.0, so in the first two years after application the mineral fertiliser rates calculated as outlined above can be reduced by the following quantities (Table 12):

Table 12. Mean nutrient quantities supplied by farm flurry (Árendás 1995)

Year	N		P_2O_5		K_2O	
			kg/m³			
	thick (1:1)	thin (1:3)	thick (1:1)	thin (1:3)	thick (1:1)	thin (1:3)
Year 1	0.8	0.3	0.6	0.2	1.5	0.5
Year 2	0.4	0.1	0.3	0.1	0.9	0.3
Total	1.2	0.4	0.9	0.3	2.4	0.8

If exact data are available on the nutrient content of the slurry, the same mineral fertiliser equivalence factors can be used to determine the quantities of mineral fertiliser active agents replaced by the slurry.

5.3. Effect of forecrops: Forecrop effects that reduce the N mineral fertiliser requirement

– After leguminous forecrops the N mineral fertiliser requirement decreases as follows (Table 13):

Table 13. Reduction in N mineral fertiliser requirement after leguminous forecrops (Árendás 1995)

Leguminous forecrop	Long-term effect	N kg/ha
Alfalfa	Year 1*	–30
	Year 2	–50
Red clover	Year 1	–30
	Year 2	–20
Annual legumes or fodder mix containing legumes		–25

*If ploughed up late (after 15 September) no correction is used (0 kg N/ha)

– In the case of early-harvested forecrops (prior to 15 September) and a spring-sown crop, the N mineral fertiliser requirement will decrease as follows, depending on the soil texture, due to N mineralisation in autumn (Table 14):

Table 14. Modification in N mineral fertiliser requirement of spring-sown crops after forecrops harvested in summer (Árendás and Csathó 1998, using data from Győrffy)

Soil texture	N kg/ha
Sand	–0
Sandy loam	–10
Loam	–30
Clay loam	–20
Clay	–10

5.4. Effect of forecrops: Forecrop effects that *<u>reduce</u>* *the K fertiliser requirement*

If chopped or burnt crop residues are incorporated into the soil, the K_2O requirement can be reduced by *10 kg/t grain after cereals and maize* and by *30 kg after sunflower*.

This reduction in the K fertiliser requirement should be multiplied by the following correction factors, depending on the K-supplying ability of the soil:

Very poor: 0.25; poor: 0.50; medium: 0.75; good, very good, excessive: 1.00.

6. Recommendations provided by the new system for meso- and microelement fertilisation and liming

The new cost- and environment-friendly fertiliser recommendation system also provides recommendations on the necessary doses of Ca, Mg, Zn, Cu, Mn and B.

The system provides recommendations on Mg doses for all 30 crops on soils with poor or medium Mg supplies. In the new system such soils are only found on areas with sand or sandy loam texture. The minimum and environment-friendly variants use specific factors of 1.5 in the case of poor supplies and 1.0 for medium supplies, while the factors for the balance-based and integrated variants are 2.0 for poor supplies and 1.5 for medium supplies.

The new system attaches special importance to zinc, as deficiencies in this element have been reported in many areas. The soil Zn supply categories are somewhat lower than those used in the intensive system. The recommended Zn doses change not only according to the soil Zn supplies, but also as a function of lime status and P supplies. In the case of higher lime content and better P supplies, higher Zn doses are recommended on Zn-deficient areas. At the minimum and environment-friendly levels 1.5 kg/ha Zn is recommended in the form of foliar spray, while at the balance-based and integrated levels 5–25 kg/ha Zn should be incorporated into the soil. The system only recommends Zn fertilisation for crops with a high Zn requirement (maize, sorghum, soybeans, oil flax, fibre flax), and the long-term effect is considered when the Zn is incorporated into the soil.

The Mn supply categories are also somewhat lower than those applied in the MÉM NAK (1979) system. The area of Mn-deficient soil in Hungary is negligible, so the doses recommended for soil incorporation range from 0.3 kg/ha for beans to 1.0 kg/ha for sugar beet.

The situation is similar for copper. On Cu-deficient areas a foliar dose of 0.1 kg/ha is recommended for winter barley, spring fodder barley, oats, alfalfa and flax and 0.2 kg/ha for winter wheat, sunflower, hemp and fodder beet.

The hot water boron supply categories were elaborated chiefly based on international data. On boron-deficient areas the recommended rates are 2.4 kg/ha for alfalfa, red clover and fodder beet and 3.2 kg/ha for sugar beet. Boron fertilisation is not recommended for other crops.

At the minimum and environment-friendly levels of the liming recommendations, ¼ lime doses are recommended on sand, sandy loam and loam soils and ½ doses on clay loam and clay. In the balance-based and integrated variants, ½ lime doses are recommended on sand, sandy loam and loam soils and full doses on clay loam and clay.

7. Recommended literature

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