Dynamics of P and K in Calcareous Sandy Soils in the Danube—Tisza Interfluve

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16% of the arable land in Hungary is covered with sandy soils. Most part of these soils is situated in the Danube—Tisza interfluve. The fertility of these sandy soils is greatly dependent on soil properties, such as nutrient supply and water regime. Nutrient supply is determined by several factors, such as the nutrient reserve of the soil and the degree of their availability for plants.

The calcareous sandy soils of the Danube—Tisza interfluve are poor in plant nutrients, their humus, nitrogen, phosphorus and potassium contents are low [10] and this is the limiting factor of their fertility. One of the most important preconditions of vine-growing is the ensurance of the optimum nutrient supply [4].

Prof. 'SIGMOND pointed out: "It is the natural function of soil to serve both as physical support and as the source of food for vegetation." There is a close relationship between the type and the nutrient content of soils because the soil processes regulate the nutrient content [9]. Therefore — when applying mineral fertilizers — a twofold influence must be taken into consideration: the influence of fertilizers on the soil; the influence of the soil on fertilizers [7].

"Not only the absolute quantity of nutrients is of importance, but also their activity. The absorption complex of the soil may contain several important plant nutrients (Ca, K, Mg)" [10]. The quantity and saturation of the absorption complex are important even in the case of such plant nutrients which are not present in it, e.g. phosphorus. For the characterization of the nutrient status of a soil, the various soil properties must be taken into consideration and the proper methods must be chosen for the determination. 'SIGMOND emphasized: "When fixing the limit values of certain plant foods it is a great mistake to give rigid figures . . . It is very probable that the limit values may vary according to the soil type which best represents the general character of the dynamic changes taking place in a soil" [10].

He also realized the great importance of determining the available nutrient content of soils for the evaluation of their nutrient status. The evaluation and interpretation of data is a highly complicated process, requiring great care, in the course of which soil formation processes must also be taken into consideration [9].

Several authors maintain that a certain nutrient concentration is necessary for ensuring an optimum and continuous nutrient supply of grape. The values, however, given as the "optimum nutrient concentration" differ in the various papers. According to ENGELS, STELLWAG, KNICKMANN, KOZMA [4], MOSER [5] this value for P_2O_5 is 30 mg/100 g soil, while TERTS [11] considers the phosphorus supply as optimal if the available P_2O_5 content is 20, 15 and 10 mg/100 g soil at a depth of 0–20, 20—40 and 40—60 cm, respectively.

The optimum content of available K is determined by ENGELS, STELLWAG, KNICKMANN, KOZMA [4], MOSER [5] as a function of lime supply, while HILLEBRAND [3], ÉBÉNYI [1], FEKETE [2], PLATZ [6], TERTS [11] calculate it as a function of texture.

The limit values given by various authors differ considerably. According to 'SIGMOND the differences in the chemical methods used for the determination of the soluble, available and stored nutrient contents partly explain the deviations. Besides the actual nutrient resources of a soil (the amount of available and soluble nutrients) the dynamics of nutrients, directly influenced by the soil processes, are also of great importance. It is quite clear from the above that several factors must be taken into consideration when the limit values for a given soil are determined.

Materials and methods

The effects of mineral fertilizers on the available P and K contents of the soil, as well as the various factors influencing the "building-up" of nutrient reserve in the soil were studied in field experiments carried out in vineyards on blown sand and slightly humous sandy soils of the Danube–Tisza interfluve in 1968.

The grape variety was "Kadarka", the row and stock distance 2.4 m by 0.8 m.

Experimental field No. 1 (Kiskunhalas)

Soil type: blown sand.
Topography: almost flat plain.
Depth of water table: 2 m.
Texture: sand, mainly coarse sand.
Chemical characteristics: slightly alkaline; the calcium carbonate content is moderate. Cation exchange capacity is very low. Ca^{2+} ions dominate. Due to the high water table and its periodical fluctuation, the relative quantity of absorbed Mg^{2+} is also considerable. Available P and K contents are low within the whole profile and it is almost totally deficient in humus.

Experimental field No. 2 (Kiskőrös)

Soil type: slightly humous sandy soil.
Depth of water table: below 3 m.
Texture: sand, coarse sand.
Chemical characteristics: slightly alkaline; the calcium carbonate content is moderate. CEC is rather low, but higher than in the soil of Experimental Field No. 1, due to the higher humus and physical clay contents. Ca^{2+} prevails among the absorbed cations. The depth of humus layer is 35 cm. The soil is poor in humus. Available P and K contents are low in the surface layer and decrease further in deeper layers.

Table 1

Some relevant analytical data of the experimental soils

Spot No.	Sampling depth, cm	Mechanical composition, %								pH (H_2O)	$CaCO_3$ %	Humus %	Available	
		particle size, mm						Physical sand	Physical clay				P_2O_5	K_2O
		3–1	1–0.25	0.25–0.05	0.05–0.01	0.01–0.001	<0.001						mg/100 g of soil	
1.	0– 10	0.02	8.39	87.85	0.76	0.36	2.62	97.02	2.98	7.6	7.56	0.56	5.2	9.0
	10– 20	0.01	8.49	87.76	0.66	0.46	2.62	96.92	3.08	7.6	6.30	0.58	6.0	7.1
	20– 30	0.10	6.41	88.75	0.94	0.58	3.22	96.20	3.80	7.7	6.72	0.34	3.8	5.0
	30– 40	0.05	8.11	87.44	0.80	0.44	3.16	96.40	3.60	7.7	7.14	0.26	4.0	4.8
	40– 50	—	5.38	90.06	1.08	0.48	3.00	96.52	3.48	7.7	7.35		4.1	5.0
	50– 60	—	12.07	83.63	0.74	0.26	3.30	96.44	3.56	7.7	6.72		3.8	4.0
	60– 70	0.04	6.07	89.11	1.38	0.46	2.94	96.60	3.40	7.8	6.93		3.6	2.6
	70– 80	0.02	11.27	84.75	0.82	0.32	2.82	96.86	3.14	7.8	5.88		3.0	2.4
	80– 90	0.02	6.85	89.21	0.64	0.20	3.08	96.72	3.28	7.8	5.04		2.9	2.4
	90–100	0.02	5.66	89.20	1.20	0.82	3.10	96.08	3.92	7.8	6.72		3.0	2.4
2.	0– 10	0.42	9.59	83.42	0.78	1.85	3.94	94.21	5.79	7.4	6.15	0.73	9.8	4.6
	10– 20	0.48	6.97	85.26	1.16	2.13	4.00	93.87	6.13	7.5	4.51	0.74	9.2	6.8
	20– 30	0.50	12.58	79.98	1.20	1.48	4.26	94.26	5.74	7.5	5.74	0.75	8.0	7.0
	30– 40	0.20	8.70	83.34	1.56	1.72	4.48	93.80	6.20	7.8	7.38	0.59	4.8	4.1
	40– 50	0.20	5.67	88.23	0.74	0.96	4.20	94.84	5.16	7.8	10.25		3.2	4.0
	50– 60	0.25	7.64	86.33	0.62	0.96	4.20	94.84	5.16	7.9	8.76		3.0	3.4
	60– 70	0.20	7.38	86.90	0.38	0.72	4.42	94.86	5.14	7.8	8.86		2.8	3.2
	70– 80	0.08	6.45	88.13	0.28	0.94	4.12	94.94	5.06	7.7	8.19		2.2	3.2
	80– 90	0.10	7.69	85.36	0.87	1.08	4.90	94.02	5.98	7.7	6.80		2.2	3.2
	90–100	0.18	7.50	85.69	0.92	1.17	4.54	94.29	5.71	7.7	7.20		2.2	3.2
3.	0– 10	0.04	8.56	83.55	1.13	1.92	4.80	93.28	6.72	7.4	3.07	1.11	9.4	8.0
	10– 20	0.56	7.43	84.74	1.27	0.98	5.02	94.00	6.00	7.4	2.46	1.08	9.2	8.2
	20– 30	0.40	9.58	82.57	1.19	1.44	4.82	93.74	6.26	7.4	2.46	1.07	9.2	8.4
	30– 40	0.27	8.80	82.73	1.48	1.96	4.76	93.28	6.72	7.4	2.66	0.92	5.3	8.4
	40– 50	0.29	7.58	84.22	1.07	1.16	5.68	93.16	6.84	7.5	2.05		4.6	6.3
	50– 60	0.13	10.70	82.04	0.93	1.18	5.02	93.80	6.20	7.7	4.31		2.8	5.8
	60– 70	0.08	8.76	85.58	0.58	1.08	3.92	95.00	5.00	7.6	5.74		2.2	5.8
	70– 80	0.10	7.40	86.87	0.73	1.12	3.78	95.10	4.90	7.5	11.07		2.2	5.0
	80– 90	0.18	6.80	87.89	0.39	1.30	3.44	95.26	4.74	7.7	17.87		2.3	4.2
	90–100	0.12	7.20	87.40	0.49	1.32	3.47	95.21	4.79	7.7	16.40		2.2	4.2

Table 2

Exchangeable cations in the experimental soils

Spot No.	Sampling depth, cm	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}
		me/100 g soil					in % of CEC			
1.	0 – 10	4.77	0.67	0.52	0.12	6.08	78.45	11.02	8.55	1.98
	10 – 20	4.67	0.62	0.48	0.10	5.87	79.56	10.56	8.18	1.70
	20 – 30	4.50	0.80	0.53	0.15	5.98	75.25	13.38	8.86	2.51
	30 – 40	4.98	0.72	0.40	0.10	6.20	80.33	11.61	6.45	1.61
	40 – 50	3.57	0.70	0.38	0.15	4.80	74.37	14.59	7.91	3.13
	50 – 60	3.71	0.69	0.30	0.20	4.90	75.71	14.08	6.12	4.09
	60 – 70	3.99	0.67	0.24	0.20	5.10	78.23	13.13	4.71	3.93
	70 – 80	3.96	0.82	0.20	0.20	5.18	76.45	15.83	3.86	3.86
	80 – 90	3.57	0.78	0.20	0.15	4.70	75.95	16.59	4.25	3.21
	90 – 100	3.65	0.80	0.20	0.15	4.80	76.05	16.66	4.16	3.13
2.	0 – 10	6.41	0.80	0.28	0.05	7.54	85.01	10.62	3.71	0.66
	10 – 20	6.99	0.76	0.40	0.05	8.20	85.25	9.27	4.87	0.61
	20 – 30	7.33	0.82	0.27	0.05	8.57	86.54	9.58	3.29	0.59
	30 – 40	8.17	0.50	0.08	0.05	8.80	92.84	5.69	0.90	0.57
	40 – 50	7.20	0.50	0.10	0.05	7.85	91.73	6.36	1.27	0.64
	50 – 60	5.05	0.50	0.10	0.05	5.70	88.60	8.77	1.75	0.88
	60 – 70	5.13	0.50	0.12	0.10	5.85	87.69	8.54	2.05	1.72
	70 – 80	5.29	0.50	0.08	0.10	5.97	88.60	8.38	1.34	1.68
	80 – 90	3.82	0.70	0.08	0.10	4.70	81.28	14.89	1.70	2.13
	90 – 100	3.82	0.70	0.08	0.10	4.70	81.28	14.89	1.70	2.13
3.	0 – 10	7.22	1.06	0.80	—	9.08	79.52	11.67	8.81	—
	10 – 20	11.12	1.11	0.25	—	12.48	89.10	8.89	2.01	—
	20 – 30	11.29	0.96	0.21	0.05	12.51	90.25	7.67	1.68	0.40
	30 – 40	10.43	0.87	0.40	0.10	11.80	88.39	7.37	3.39	0.85
	40 – 50	7.91	1.10	0.32	0.10	9.43	83.88	11.67	3.39	1.06
	50 – 60	7.90	1.08	0.30	0.16	9.44	83.68	11.44	3.17	1.71
	60 – 70	7.12	1.12	0.20	0.16	8.60	82.79	13.02	2.32	1.87
	70 – 80	4.72	0.75	0.22	0.10	5.79	81.52	12.95	3.79	1.74
	80 – 90	3.36	0.70	0.18	0.15	4.39	76.54	15.95	4.10	3.41
	90 – 100	3.45	0.72	0.18	0.15	4.50	76.66	16.00	4.00	3.34

Experimental field No. 3 (Soltvadkert)

Soil type: humous sand (with higher humus and physical clay contents than the soil of Experimental Field No. 2).
Topography: almost flat plain.
Depth of water table: 3 m.
Texture: sand; higher percentage of fine sand and clay fraction than in the soil of Experimental Field No. 2.
Chemical characteristics: slightly alkaline; the calcium carbonate content is moderate. Low CEC, but higher than that in plots No. 1 and 2. Ca^{2+} prevails among the absorbed cations. Available P and K contents are low in the surface layers, and decrease further with depth.

The data of soil analyses are given in Tables 1 and 2.

From 1968 174 kg N/ha, 205 P_2O_5/ha, 417 kg K_2O/ha were applied annually on the experimental plots. P and K were ploughed into the soil at a 40 – 80 cm distance from the stocks, while N was spread on the surface. The application of fertilizers in stripes — which actually tribled their quantity — enabled us to study the "building up" of nutrient reserves as well.

In the autumn of 1971, i.e. after three years of fertilization, a detailed soil analysis was carried out. Three ditches (each 240 cm long and 100 cm deep) were dug both on the fertilized and the unfertilized parcels on each experimental field. The ditches intersected the rows of the stocks at right angles. The length of the ditches was divided into 12 equal sections, 6 to the right and 6 to the left from the vine-stocks. The soil columns corresponding to each section were divided vertically into 10 layers, and soil samples were taken from each. Thus 120 soil samples were collected from one ditch and the available phosphorus and potassium contents were determined.

The data of the three replicate ditches were averaged. Each value in the graphs (Figs 1—3) represents the average of data obtained by the analysis of 36 soil samples.

Results and discussion

The analytical data indicate that there was an increase in the available phosphorus and potassium contents of the soil profiles in each experimental field, due to the regular application of high doses of fertilizers. However, the degree of the increase was different in the various soil types.

On Experimental Field No. 1 (blown sand with very low clay, humus and plant nutrient content), the originally very low phosphorus content (2—3 mg P_2O_5/100 g soil) increased to 15—22 mg P_2O_5/100 g soil in the fertilized stripe at the depth of application. Phosphorus migrated neither vertically downwards nor horizontally towards the neighbouring unfertilized stripes. Available K_2O content increased from 4—5 mg/100 g soil to 12—16 mg/100 g soil in the treated stripes to the depth of application. Potassium migrated slightly downwards, but sideways the K_2O content was almost the same as in the untreated sand (Fig. 1).

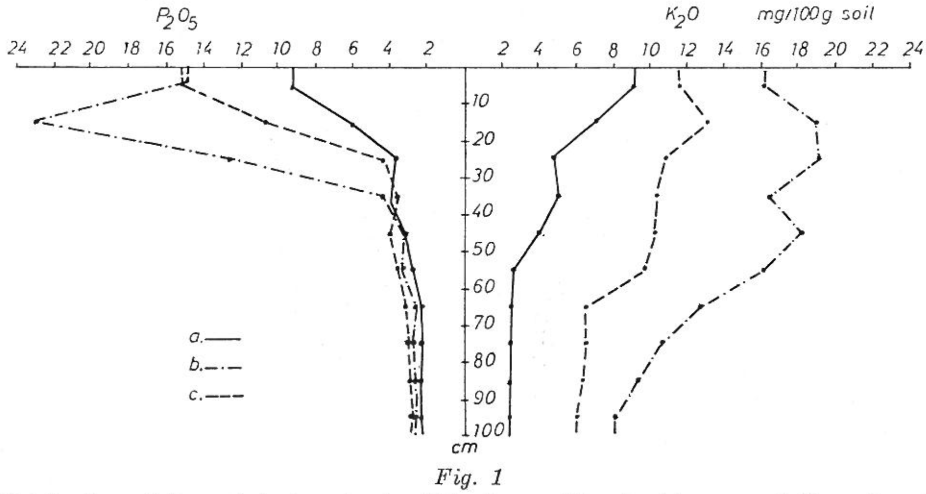

Fig. 1

Distribution of the nutrient content within the profile of a blown sand (Experimental field No. 1) after 3 years' fertilizing in stripes. Distance from the stock: a. 0—40 cm; b. 40—80 cm; c. 80—120 cm

On Experimental Field No. 2 (slightly humous sand soil with somewhat higher nutrient and inorganic and organic colloidal contents) the initial value of P_2O_5 was 6–8 mg/100 g soil and it increased to 18–24 mg/100 g soil at 35 cm below the surface, and P migrated neither vertically nor horizontally. At the same depth the K_2O content increased to 25–28 mg/100 g soil; in the deeper layers the increase was slight (Fig. 2). The greater original nutrient and colloidal contents of the soil facilitated the "building up" of nutrient reserves to a higher extent.

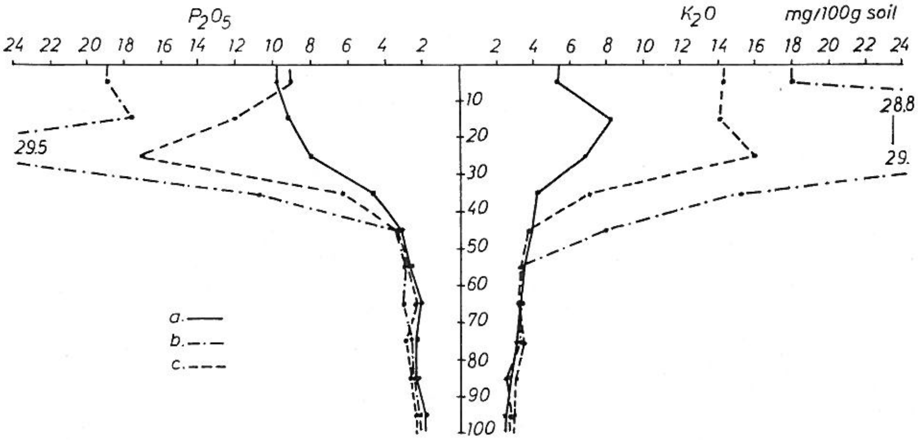

Fig. 2

Distribution of the nutrient content within the profile of a sandy soil (Experimental field No. 2) after 3 years' fertilizing in stripes. Distance from stock: a. 0–40 cm; b. 40–80 cm; c. 80–120 cm

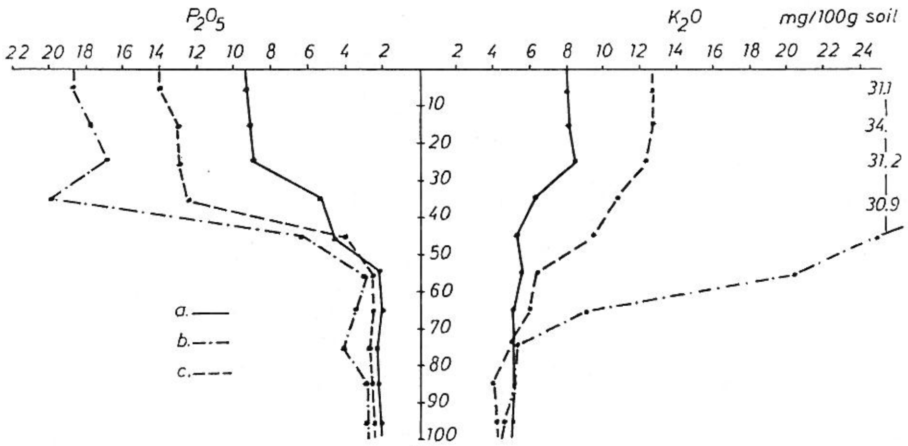

Fig. 3

Distribution of the nutrient content within the profile of a sandy soil (Experimental field No. 3) after 3 years' fertilizing in stripes. Distance from stock: a. 0–40 cm; b. 40–80 cm; c. 80–120 cm

On Experimental Field No. 3 (humous sand soil with the highest nutrient and colloidal substance contents as compared to the other soils studied) the available P_2O_5 content increased to 18–20 mg/100 g soil and the K_2O content to 30 mg/100 g soil in the fertilized stripe. Migration was observed only in the case of K_2O, downwards. Comparing the data obtained from Experimental Fields No. 2 and 3 it can be concluded that in the case of identical nutrient doses, and almost identical rate of uptake, the degree of nutrient "saturation" depends to a great extent on the original nutrient content of the soil (Fig. 3).

Conclusions

The nutrient content of the soil can be increased with high doses of fertilizers applied for several years. Potassium — added with fertilizers — slightly migrates downwards but phosphorus remains at the depth of application. Thus the roots are supplied with nutrients only in the case of deep fertilizing. The level of nutrient supply depends on the soil properties to a great extent. Its limit value is low in case of soils with low organic and inorganic colloid contents and low absorption capacity. In soils with high organic and inorganic colloid contents the limit value is also high. Consequently the limit values must be accurately determined. It is advisable to take into consideration the texture and the adsorption capacity of the soil when the level of optimum nutrient supply in a plantation is determined, and it must be kept in mind that this level must be high also in deeper layers. The rate of the increase in the nutrient content must be determined also on this basis.

Summary

Experiments were carried out on blown sand and slightly humous sands of the Danube–Tisza interfluve for studying the effect of fertilizing on the available P and K contents of the soils. The soil properties influencing the levels of nutrient supply were also determined. As a consequence of regular fertilizer application, the available P and K contents of the soils increased.

The rate of the increase was influenced by the original nutrient content of the soil. It was higher in soils with higher initial nutrient content (Figs 1–3). Several other factors also affect the rate of the increase. In blown sand with very low organic and inorganic colloid contents and low absorption capacity, the K_2O content increased to 18–20 mg/100 g soil in the treated layers, while in the slightly humous sandy soil with higher organic and inorganic colloid contents it increased to 25–30 mg/100 g soil. On the soil types studied the reserve of available P_2O_5 content may be increased to 20 mg/100 g soil.

On plantations, where a higher rate of nutrient supply is necessary not only on the surface but in deeper layers as well, besides the measurement of the soil's available nutrient content, the determination of soil texture and absorption capacity is also necessary and must be taken into consideration in selecting the most appropriate method of fertilizer application.

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