The Value of Residual Fertilizer NPK and Phosphorus in a Long-Term Experiment

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Before the Second World War superphosphate was the most frequently used mineral fertilizer in our country. Its effectiveness and the phosporus supply of our soils were studied by Prof. ALEXIUS A. J. DE 'SIGMOND himself.

In the last decade the amount of applied fertilizers has increased considerably in Hungary. In the years 1960—64 the phosphorus balance of our soils was already equilibrated [11] and in the recent years it has become positive. In the years 1970—72, 45—48 kg/ha P_2O_5 was given into the soil, on the average, and only 25—30 kg/ha P_2O_5 was taken up, thus the phosphorus content of our soils increased roughly by 20 kg/ha P_2O_5. The problems of to what extent phosphorus compounds accumulated in the soil are available to crops and to what extent the phosphorus pool has to be increased in the soil, have become of topical interest.

Numerous problems of phosphate fertilization have been illuminated by recent research. The fate of phosphorus in soil was represented by LARSEN [18] by the following scheme:

$$\begin{array}{ccccccc} & & P_{plant} & & & & \\ & & \uparrow & & & & \\ P_{\substack{fertilizer\\ solid}} & \rightarrow & P_{sotution} & \rightarrow & P_{labile} & \rightarrow & P_{non\text{-}labile} \\ & & \downarrow & & & & \\ & & P_{drain\ water} & & & & \end{array}$$

The increase in the labile pool brought about by the application of fertilizer phosphorus is only temporary, and decreases exponentially. This decrease is best expressed as a half-life [17]. LARSEN [18] showed that a metastable form of fertilizer phosphate existed between the labile form and the inert fraction, and this metastable phosphate was mobilized during exhaustive cropping.

The residual value of phosphate fertilizers depends both on the reaction products formed in the soil and on the distribution and movement of added phosphorus.

At Rothamsted and Woburn the effect of a new dressing of P was measured on the yield of crops grown on soils with and without P residues. In these experiments all corps gave larger yield on enriched soils than on starved soils when new P was not given but fresh N and K were. When new P was given, crops gave the same or almost the same yield on starved and

enriched soils. The apparent recovery of P was 0,5 to 1% per year of the total amount of P applied between 1856 and 1901 [12].

Similar results are published by RUSSELL on Sherborne soils where the same effect was achieved by lower amounts of phosphorus fertilizers on plots with "old" residues as by higher amounts on plots with "new" phosphorus residues [26]. Residues had an average efficiency of about 24 per cent after one year, and approximately 3 per cent after seven years, compared with fresh fertilizer phosphorus [30].

Mean percentages of "fresh" superphosphate equivalents of residues decreased from 20—40% after 1 year to about 10—15% after 6 years for different crops, on neutral soil. In contrast to these results, in a slightly calcareous soil yields did not decline significantly between the first and fourth years after application [24].

Similar results have been published in many parts of the world concerning the value of P residues, e.g. in Finland [13]. Germany [28, 29], USSR [15], Australia [4 19, 20,], India [1, 5] Rhodesia [27], South-Africa [7], USA [23, 14], and Canada [25].

The problems of nitrogen fertilization are different from those of phosphorus: they result more from leaching than from fixation. So the efficiency of N residues is influenced by all the factors which have an effect on leaching of nitrate and on nitrification of ammonium: texture and acidity of soil, precipitation, etc. [8].

Nitrogen residues can increase yield 1) because some nitrogen applied for but not used by the previous crop remaining in the soil is available to the following crop; 2) because fertilizing with N increases the plant residues that decompose in soil [8]. Sometimes the first effect is not observable, as on the Exhaustion Land at Rothamsted [12], or does not last more than 1 year [12, 21, 9, 16, 6, 10, 22]. The second one can be effective for 5—10 years [8] but it is less effective than the first one [12].

The above mentioned data show the magnitude of the effect of fertilizer residues, but there are few data concerning the apparent recovery of fertilizers with and without considering the effect of their residues, that is, how the apparent recovery increases if the residual effects are taken into account.

In our experiments we studied the direct and residual effects of NPK and P fertilizers on a chernozem-type soil common in Hungary.

Experimental

The experiment was carried out in the period between 1957 and 1968 at Martonvásár and described in detail in previous publications [2, 3]. Its original aim was to compare the effects of FYM and mineral NPK. Treatments were: 1) unmanured; 2) FYM 150 ton/ha/12 years; 3) mineral NPK containing the same amount of NPK as FYM (N = 1200 kg/ha, P_2O_5 = 870 kg/ha and K_2O = 1060 kg/ha for 12 years); 4) 1/2 FYM + 1/2 mineral NPK. There were also two other treatments which are not discussed here. N was applied as ammonium nitrate with calcium carbonate, P as superphosphate, and K as potassium chloride. P and K and half of the N dose were applied in the autumn, broadcast by hand and ploughed down, the other half was added in spring, broadcast before drilling for maize and as topdressing for winter-wheat. FYM was cattle

dung, applied every four years and analysed for NPK. Test crops were maize and winter-wheat.

The design of the experiment was 6×6 latin square.

The soil of the experimental field is a chernozem with forest residues. It is a loam, the pH is between 7,2—7,4; the organic matter content is 2,5—2,8% and the AL-soluble P_2O_5 and K_2O amount to 3—4 and 18—20 mg/100 g soil, respectively.

The yields and nutrient contents of crops as well as the apparent recoveries of NPK during the 12 years were described by author [2,3].

After 12 years, both FYM and mineral NPK dressings were stopped but the measuring of yield was continued.

In the 13th year (1969) no fertilizer was applied, thus yields showed the residual effect of NPK. In order to measure the residual effects of NPK and PK separately, in the 14th year (1970) the plots were divided into two parts. One half was left untreated to determine the effect of NPK residues, and to the other half 100 kg/ha N was added to measure the residual effect of PK. The plots were treated in the same manner in the 15th and 16th years, as well. The test crop was sweet Sudan grass every year.

Results and discussion

The effects and residual effects of FYM and mineral NPK applied for 12 years are shown in Tables 1 and 2. The residual effect of NPK — limited by N — was considerable for 1969—72. The residual effect of mineral fertilizers

Table 1

Effect of FYM and mineral NPK on the yield of maize and winter wheat (Martonvásár, Hungary, 1957—68)

Treatment	Mean yield			Nutrient content					
	grain with 86% dry matter content			N	D	P_2O_5	D	K_2O	D
	ton/ha response, %			kg/ha/year					
1. Unmanured	3.15	—	100	5.81	—	2.10	—	4.59	—
2. FYM	4.49	1.34	143	9.47	3.66	3.46	1.36	6.86	2.27
3. Min. NPK	4.83	1.68	153	11.19	5.38	3.85	1.75	8.16	3.57
4. 1/2 FYM + 1/2 min NPK	4.67	1.52	148	10.26	4.45	3.70	1.60	7.72	3.13

FYM = 60 ton/ha/4 years with 400 kg N, 292 kg P_2O_5, 352 kg K_2O.
Mean mineral fertilizer doses = 100 kg N, 73 kg P_2O_5, 88 kg K_2O every year.
D = difference.

was somewhat larger and higher in per cent of the accumulated direct effect of 12 years than that of FYM. Table 2 shows similar effects for 1970—72. The residual NPK effects are much less than in 1969—72. This is due to the rather large residual effects in 1969 which decreased in the second and third years

Table 2

Residual effect of FYM and mineral NPK (Martonvásár, Hungary)

Treatment	A. Yield of Sudan grass, hay at 86% dry matter, ton/ha									
	Effect of NPK residues 1969—72			Effect of NPK residues 1970—72			Effect of P/K residues 1970—72			
	ton/ha	D	%	ton/ha	D_1	%	ton/ha	D_2	%	D_1-D_2
1. Unmanured	5.31	—	100	4.84	—	100	8.54	—	100	—
2. FYM	6.46	1.15	122	5.32	0.48	110	10.62	2.08	125	1.60
3. Min. NPK	6.96	1.65	131	5.49	0.65	113	10.94	2.31	128	1.66
4. 1/2 FYM + + 1/2 min. NPK	6.86	1.55	129	5.52	0.68	114	10.11	1.57	117	0.89
$LSD_{5\%}$		0.58	11		0.48	10		0.48	6	0.68

	B. Nutrient content of Sudan grass, kg/ha/year								
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1. Unmanured	44.8	15.5	89.9	37.4	16.3	75.5	76.1	20.0	105.9
2. FYM	51.6	28.8	114.6	37.8	23.6	88.5	89.1	33.6	109.5
3. Min. NPK	56.5	31.2	125.4	37.9	25.4	88.5	101.4	42.4	135.4
4. 1/2 FYM + + 1/2 min. NPK	54.4	29.8	120.7	38.8	24.0	87.0	94.0	38.5	122.0

and disappeared by the fourth year. This can be explained by the fact that there was no N effect in the fourth year.

At the same time, PK residues with new N (Table 2) gave one-and-a-half or twice as much increase than without it.

NPK uptakes show similar trends as yields. Fresh N increased not only the N but also the P content of plants. N residues increased N uptake only in the first year while with fresh N it was found that PK residues exerted their effect even in the fourth year, as no deficiency of N impeded PK efficiency, though P uptake diminished in the second, third and fourth years. This fact, as well as plant and soil analyses — not discussed here — showed that K had neither effect nor residual effect in this soil. For this reason, P can be considered as responsible for the extra yields with fresh N.

Table 3 shows the apparent recoveries of nutrients for the 12 years of fertilizer application and for the four or three years of residual effects, with and without fresh N. The data in Table 3 indicate that the apparent recovery of N increased by about 10%, while that of P increased by 50—60% with fresh N during the four years of measuring the residual effects, in terms of the apparent recoveries of the 12 years of fertilizer application. Without giving fresh N, the increase of the apparent recovery of P was only the half of that with fresh N.

In all probability, the residual effect of P does not cease to exist in the fourth year, it lasts further on.

Table 3

Apparent recovery percentage of nutrients (Martonvásár, 1957—72)

Year	FYM	Extra uptake	Mineral NPK	Extra uptake	1/2 FYM + 1/2 mineral NPK	Extra uptake
			Nitrogen			
1957—68	36.2		52.9		43.9	
1957—72, with N residues	38.5	2.3	56.8	3.9	47.1	3.2
1957—72, with fresh N	41.0	4.8	58.0	5.1	48.7	4.8
			Phosphorus			
1957—68	18.7		24.0		21.9	
1957—72, with N residues	24.7	6.0	31.0	7.0	28.4	6.5
1957—72, with fresh N	28.2	9.5	36.6	12.6	33.3	11.4
			Potassium			
1957—68	24.5		40.5		35.1	
1957—72, with N residues	33.3	8.8	54.0	13.5	46.7	11.6
1957—72, with fresh N	38.8	14.3	67.0	26.5	56.5	21.4

The experimental results indicate that in this soil the residues of FYM had no larger effect than those of mineral NPK. Neither yields nor apparent recoveries obtained with FYM were superior to those obtained with NPK.

Summary

The aim of the experiments carried on for 12 years was to compare the effects of FYM and mineral NPK by the following treatments: 1) Unmanured; 2) FYM, 150 ton/ha/12 years; 3) Mineral fertilizers, containing the same amount of NPK as FYM (N = 1200 kg/ha/12 years, P_2O_5 = 870 kg/ha/12 years, and K_2O = 1060 kg/ha/12 years) in the form of ammonium nitrate with calcium carbonate, superphosphate, and potassium chloride; 4) 1/2 FYM + 1/2 mineral NPK. The test crops were maize and wheat for 12 years, and Sudan grass for the residual effect.

After 12 years dressings were stopped but yields were continually measured. In the 13th year the effect of NPK residues was measured. In the 14th year the plots (100 m^2) were divided into two parts and 100 kg/ha fresh N was given to one half in order to measure the effect of PK residues.

The effect of NPK residues limited by N was observable in the yield practically only in the first year, and in the nutrient uptake for 3 years. PK residues with fresh N increased the yield much more than they did with N residues and this was observable even in the fourth year.

During four years after the application of dressings the residual effects increased the apparent recovery of N by about 10%, and that of phosphorus by 50% in terms of the apparent recoveries of 12 years' dressings. The residues of FYM had no larger effect than those of mineral NPK, and did not exert it longer.

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