Fertilizer regime and changes in the phosphate and potash status of a silty marine clay soil during 25 years*

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Abstract. Changes in the soil phosphorus and potassium status on three farming systems in the Northeast Polder during 25 years are related to the fertilizer regime over this period.

The changes in the nutrient status of the soil are reflected in fertilizer policy. High *rates of phosphate dressings markedly increased the phosphate status of the soil and* built up a reserve of phosphate. In contrast, the potassium status decreased by about half, because only potatoes in the rotation were dressed with potassium.

Methods of fertilization are discussed and suggestions are made with regard to possible improvements.

Fertilizer regimes affect soil reserves of phosphate and potash. When the amounts applied are approximately equal to, or somewhat exceed, the quantities removed by cropping, reserves are maintained. A surplus increases the reserves because phosphorus and potassium are retained by the soil; too small dressings or omission of fertilizers decreases them. In general, on arable farms without organic manure the current fertilizer dressings in the Netherlands are in balance for phosphate, but there is a deficit for potassium.

Materials and methods

The opportunity arose to study changes in soluble phosphate and potash in soil with changes in the fertilizer regime on three farming systems on the experimental farm at Nagele in the Northeast Polder over a period of about 25 years. This polder was reclaimed in 1941/1942. The three adjacent systems, each comprising about 24 ha, had the same history before the experiment started and are administered by one manager. They have been under cultivation since 1952. Soil samples were taken periodically, but not annually, from all (field-scale) plots. The quantities of fertilizers applied to each plot were recorded.

The experiment, dealing with the influence of the intensity of organic

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manuring on the workability and productivity of the soil under conditions of practical farming, consists of three farming systems, viz.:

(1) Mineral fertilizers only (MF), 6 plots.

(2) 'Clover Land' (CL), 6 plots. Mineral fertilizers + green manure, such as clovers and rye grass, sown under flax and spring barley or after seed potatoes. The green manure crops, as well as leaves and tops of sugar beet, are ploughed down in autumn.

(3) Ley Farming (LF), 8 plots. Livestock is kept on this mixed farm and the 6 course, all-arable rotation in systems 1 and 2 is extended to 8 years and a 1-year temporary pasture follows both flax and spring barley. Yearly 30 tons of farmyard manure per ha is applied on 3 of the 8 plots, mostly to temporary pasture, potatoes and sugar beet. Mineral fertilizer is also applied.

The crop rotation had to be changed during the experiment; since 1964 it has been: ware potatoes, winter wheat, flax, seed potatoes, sugar beet and spring barley (50% of the land is in sugar beet and potatoes). Mineral phosphate is applied as single or triple superphosphate, mineral potash as potassium chloride and potassium magnesium sulphate.

The farms are situated on a silty marine clay soil. The top 25 cm has pH-*M* KCl 7.5, $CaCO_3$ 10%, humus 2.3% and 33% particles $< 16\,\mu m$. In the underlying subsoil thin layers of silty clay alternate with thin layers of sandy soil, sometimes with little shells. With increasing depth of the profile to 90 cm, the soil becomes somewhat lighter and from a depth of 90 cm somewhat heavier.

The results of soil analysis for phosphate and potash (top layer) have been averaged for each farming system and are presented in figure 1 for P-citr[1] (to 1957 inclusive) and P-AL[2] (since 1960), in figure 2 for Pw-value[3] (since 1965) and in figure 3 for K-HCl[4]. The average amounts of P_2O_5 and K_2O applied per ha as mineral fertilizers and in organic materials (in farmyard manure in the Ley Farming system, in the leaves and tops of sugar beet returned as green manures on the 'Clover Land', both are estimated) are also given in the figures. A number of years with about the same fertilizer dressings have been grouped together in this presentation.

Results

The phosphate status of the soil decreased slightly during the first years (figure 1). A moderate phosphate dressing was applied, because it was found in earlier experiments in the Northeast Polder that most crops, with the exception of peas and clover, responded little or not at all to phosphate dressing initially. At first, therefore, the phosphate application was lower than the removal by cropping (50–60 kg P_2O_5 per ha, except beet, which was about 100 kg P_2O_5 per ha).

After 1960 the phosphate application was increased; it exceeded that

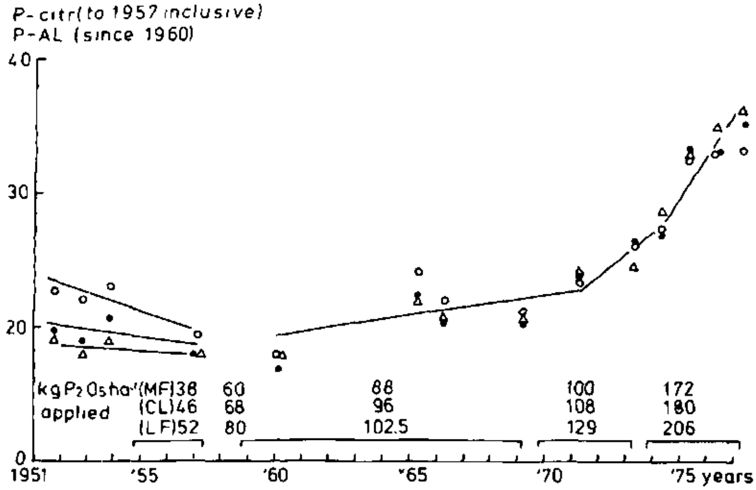

Figure 1. Change in P-citr (up to 1957 inclusive) and P-AL (since 1960) with time on three farming systems in the Northeast Polder. The average phosphate dressing for different periods is shown along the X axis. For P-citr and P-AL units, see note on p. 101. ○ Mineral Fertilizer only (MF); ● 'Clover Land', mineral fertilizer plus green manure (CL); △ Ley Farming (LF)

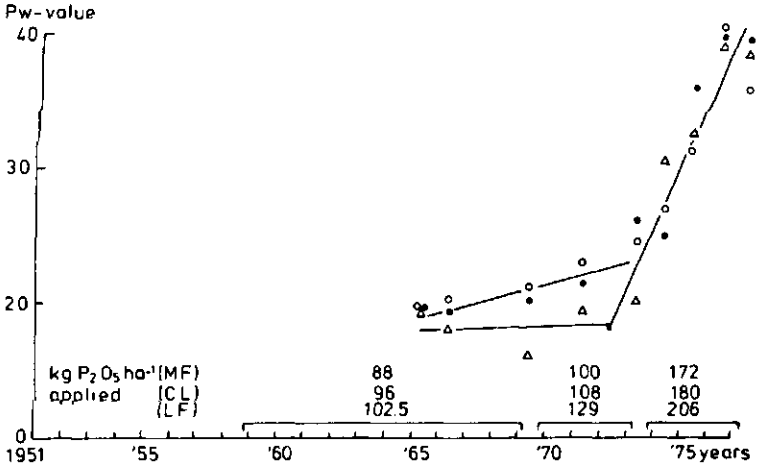

Figure 2. Change in Pw-value (since 1965) with time on three farming systems in the Northeast Polder. The average phosphate dressing for different periods is shown along the X axis. For Pw units, see note on p. 101. For explanation of symbols, see legends to figure 1

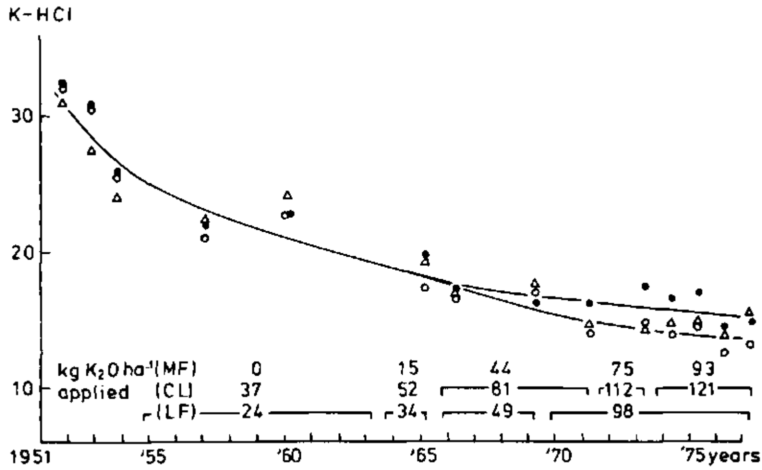

Figure 3. Change in K-HCl with time on three farming systems in the Northeast Polder. The average potash dressing for different periods is shown along the *X* axis. For K-HCl units, see note on p. 101. For explanation of symbols, see legend to figure 1

removed in the crops, and the phosphate status of the soil (P-AL) under each farming system increased markedly. Considerable enrichment occurred after 1973 (compare also figure 2 for Pw-value of the soil) when the phosphate dressing was three times larger than the phosphate removed in the crop. In the figures the changes in soil phosphate with time can be represented by straight lines. The rise in P-AL and in Pw-value decreased somewhat in 1976, perhaps because deeper ploughing mixed subsoil poorer in phosphate with the original topsoil.

Trends for P-AL are practically the same for the three farming systems. Apparently the higher yields and the larger phosphate removals with the Ley Farming system is counterbalanced by the larger phosphate dressings (about 17% more). At the beginning the Pw-value of the soil on the Ley Farming system was somewhat lower than on the other farming systems. This difference disappeared after the marked increase in Pw-value later on.

Soils were always sampled in spring (May), shortly after fertilizer dressings were applied, and this caused fluctuations in Pw-value. This was especially so after the large applications were introduced in 1974, particularly when sampling plots growing seed potatoes and spring barley which recieve phosphate in March or April. Applying phosphate to seed potatoes after the winter is done with a view to fast development right from the beginning of growth, which is favourable for early roguing. For spring barley, dressing in spring is more convenient than dressing in autumn, because this crop follows sugar beet. Higher Pw-values were due to the temporary greater availability of phosphate shortly after application and before adsorption of phosphate by the soil. Therefore, undesirable fluctuations in results occur.

High Pw-values sometimes occurred also in the case of winter wheat after phosphate dressing in autumn, probably as a result of a high concentration on some plots, where the phosphate fertilizer was incorporated superficially by means of a cultivator. In order to determine soil phosphate trends without this disturbing influence, it is recommended that sampling is delayed until the period between harvest and fertilization of the next crop. Sampling shortly after fertilization must be avoided.

The *potash content of the soil* (K-HCl) *decreased considerably with time* as a result of omission of potash fertilization or small dressings during several years (figure 3). Later, potash dressings were raised but only enough to slow *the decline in potash content. It is not certain whether an equilibrium value* has been reached, or whether the potash content will decrease further in future if the present rate of fertilization is maintained. Compared with the initial status of the soil, the K-value has now been halved. The 'Clover Land' is somewhat higher in potash, which may be attributed to the potassium returned in leaves and tops of sugar beet ploughed down and the recycling of potash in the green manures.

For the same reason as in the case of phosphate, fields dressed shortly before or in the preceding autumn (potatoes) are often somewhat higher in potash than the other ones without potash fertilization. Also in that case sampling after harvest and before fertilization of the next crop would have been preferable.

Discussion

After 1960 ample phosphate was given (in the last years up to about 185 kg P_2O_5 *per ha per year) which markedly increased the phosphate status* of the soil. Further increase seems unnecessary for the present. Excluding soils with high values, the Pw-value is now 36, averaged over all the fields. The current fertilizer recommendation in the Dutch advisory scheme for marine clay soils classified as 'ample' (Pw-value 31–45) suggests that the *phosphate dressing can be reduced, provided that the phosphate dressing* at least equals, or somewhat exceeds, removal by cropping, so that the phosphate content of the soil does not decrease too strongly. Instead of applying the same amount of phosphate to all crops, as is done now, different dressings could be used, dependent on the demand of the different crops. For marine soils of 'ample' phosphate status, the recommendations are 90 kg P_2O_5 per ha for ware potatoes and 70 kg P_2O_5 per ha for sugar beet and flax, and 30 kg for spring barley and ley pasture. Winter wheat receives no phosphate in this case. The phosphate in farmyard manure (mostly applied to ware potatoes and ley pasture) should be taken into account when deciding the amount of mineral fertilizer to be applied. Seed potatoes may be given somewhat more than ware potatoes (about 140 kg P_2O_5 per ha) to speed tuber formation and allow early roguing. Sometimes potatoes to be lifted early have a higher demand for phosphate than those to be lifted late in the season. Higher fertilizer rates for seed potatoes are justified economically, because crop returns are larger. Besides, ample phosphate somewhat increases the percentage of small tubers, which is important for seed potato production. With the Mineral Fertilizers only system and the 'Clover Land' system this means, for a crop rotation of six crops, an average of 67 kg P_2O_5 per ha per year and for the Ley Farming system, with a crop rotation of eight crops, an average of 57.5 kg P_2O_5 per ha per year. This practically balances crop removals.

At the current 'ample' soil phosphorus status, it is profitable to apply extra phosphate fertilizer to the more responsive beet crop and none to spring barley. Apart from saving labour, this practice reduces the risks of yield losses due to phosphorus deficiency in high-value crops without extra costs. Omission of a phosphate dressing for spring barley presents no drawback, because this crop usually does not respond to fresh phosphate dressings at a high soil phosphorus level, as opposed to more responsive crops like sugar beet and potatoes. Perhaps it is also advisable to apply the phosphate fertilizer for flax (second crop after potatoes) to potatoes.

Of the crops in the rotation, only potatoes were dressed with potassium. In recent years, ware potatoes are given about 350 kg K_2O per ha, and seed potatoes about 120 kg. However, seed potatoes, being a more expensive crop, could be given more fertilizer than ware potatoes, as is recommended in the case of phosphate. A higher potash dressing somewhat increases the percentage of large tubers, which may be important in the case of the Mineral Fertilizers only system, where, according to experience, the grades are too fine.

In table 1 the estimated crop removals and the amounts recommended by the Dutch Advisory Scheme at K-value[5] 14–15 (potassium supply 'sufficient') are compared for the three cropping systems.

As in the case of phosphate, the amount of potash fertilizer can be decreased by the amount contained in farmyard manure in the year of application. It is not certain if this also applies to potash contained in leaves and tops of sugar beet ploughed down on the 'Clover Land'. With the amounts recommended by the Dutch Advisory Scheme, crop removals are compensated for and in the Clover Land somewhat more than that.

Potash intended for winter wheat and flax may be applied to the preceding ware potatoes (in all 450 kg K_2O per ha). This system of fertilization gives more certainty of good potato yields without extra cost. Besides, extra potash for ware potatoes decreases the susceptibility to black spot. For the succeeding crops, which take up potash from the soil rather easily, sufficient potash remains. Except for ley pasture and seed potatoes, there is then no need to apply potash in the intervening years, unless a very responsive crop, such as onions or spinach, is grown.

Applying potash to sugar beet preceding spring barley is less desirable

Table 1. Amounts of potash removed in the crop and potash fertilizer recommendations on three farming systems in the Northeast Polder

Crop rotation	Crop removals in kg K_2O ha^{-1}			Dressing in kg K_2O ha^{-1}, according to recommendations at K-value 14 to 15		
	Mineral *Fertilizers* only	'Clover *Land*'	Ley *Farming*	Mineral *Fertilizers* only	'Clover *Land*'	Ley *Farming*
Ware potatoes	250	250	250	280	280	280
Winter wheat	75	75	75	50	50	50
Flax	95	95	95	120	120	120
Ley pasture	–	–	130[d]	–	–	170
Subtotal	420	420	550	450	450	620
Seed potatoes	*190*[a]	*190*[a]	*190*[a]	*330*[f]	*330*[f]	*330*[f]
Sugar beet	340[b]	120[c]	340[e]	120	120	120
Spring barley	85	85	85	50	50	50
Ley pasture	–	–	*130*[d]	–	–	*170*
Subtotal	615	395	745	500	500	670
Total	1035	*815*	*1295*	*950*	950	1290
Per year (rounded off)	170	135	160	160	160	160

[a]Removal 75% of ware potatoes
[b]Leaves and tops removed
[c]Leaves and tops ploughed down
[d]First cut mown, grazing afterwards
[e]Leaves and tops fed
[f]50 kg K_2O more than ware potatoes

because of luxury consumption and an adverse influence on sap purity of the beet. The amounts of potassium for each crop in table 1 is 160 kg K_2O per ha per year on average, for each of the farming systems. This is more than is now applied. The benefit of a higher dressing will be that the soil potassium reserves will no longer decrease and perhaps will increase. For ware potatoes, it is recommended that the large potash dressing, as muriate of potash, is applied in the preceding autumn, to prevent damage ot the plant caused by too high a salt concentration in the soil solution.

Notes

1 P-citr = P_2O_5 soluble in 1% citric acid (mg P_2O_5 per 100 g soil).
2 P-AL = P_2O_5 soluble in a mixture of ammonium lactate-acetic acid (mg P_2O_5 per 100 g soil).
3 Pw-value = P_2O_5 soluble in water at 20°C (mg P_2O_5 per 1 soil).
4 K-HCl = exchangeable K_2O in 0.1 M HCl (mg K_2O per 100 g soil).
5 K-HCl fraction, corrected for clay content.