NJF Report • Vol 4 • No 2 • Year 2008

Nordic Association of Agricultural Scientists

NJF Seminar 407

Long-term field experiments - a unique research platform

Sønderborg, Denmark, 16-18 June 2008

NJF
Nordic Association of Agricultural Scientists

Thirty years of growing cereal without P and K fertilization

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Introduction

The aim of a field experiment in southern Finland was to investigate how long it would take before a deficiency of the major nutrients phosphorus and potassium occurred under conditions associated with traditional crop production methods. In order to intensify the uptake both grain and straw of cereals were harvested.

Material and methods

The field experiment was established on a farm in southern Finland (60° 47' N, 24° 55' E, 110 m asl) in 1978 and it is still continuing. The field slopes to the south-east at c. 6%. At the beginning of the experiment the organic carbon concentration in the topsoil was 2.8% and its pH(H_2O) was 7.7. The soil had been cultivated conventionally for decades before the experiment started. More details are given in Jaakkola et al. (1997).

The design of the experiment consists of two factors with two levels each: without and with PK fertilizer (36 and 70 kg ha^{-1} a^{-1}, respectively) as well as without and with an extra superphosphate application (P 36 kg ha^{-1} $a^{-1)}$. The treatments were replicated at least 4 times. They were arranged in plots of 20 by 15 m or 5 by 15 m (extra superphosphate). Nitrogen has been applied at 100 kg ha^{-1} yearly. The fertilizers were placed at depths of 6-8 cm as calcium ammonium nitrate (NH_4:NO_3 = 1:1) or NPK compound fertilizer (NH_4:NO_3 ≈ 2:1).

Spring cereals were grown each year except for ryegrass for two years. Grain and straw were harvested plotwise. So was the ryegrass stand (one cutting per year). The plant samples were analyzed for N, P and K. The topsoil (plough layer, 0 – 25 cm) was sampled plotwise after harvest in certain years. In some years the subsoil (25-40 and 40-60 cm) was also sampled. Most samples were analyzed for pH and P, K, Ca, Mg extractable in acid ammonium acetate (Ac, pH 4.65, Finnish routine method).

Results and discussion

The total dry matter yield (grain + straw) decreased from about 5000 kg ha^{-1} to a level of 3000 kg ha^{-1} when only N was applied (Fig. 1). After 30 years of NP fertilizer the yield level was 4000 kg ha^{-1}. NPK application kept the yield level almost constant. The surplus annual P rate of 70 kg ha^{-1} seemed to increase the yield a little more. However, the variations between years, and even in the 5-year moving averages, were rather high for all treatments.

It is obvious that yield-reducing deficiency of potassium began to take effect in the latest 10 years. However, missing NK treatments might hide the simultaneous appearance of P deficiency.

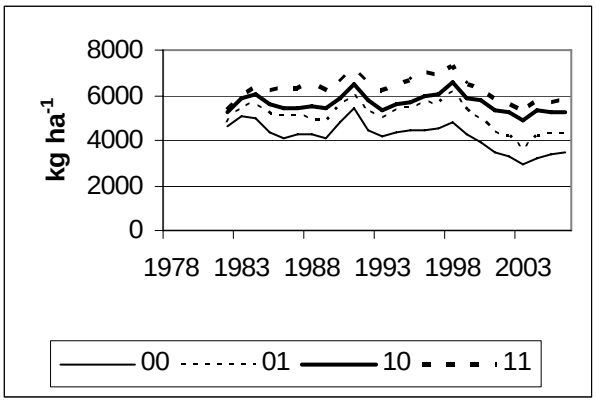

Figure 1. Moving average (5 yr) of total DM yield. 00 = N, 01 = NP, 10 = NPK, 11 = NPK+P

The P balance (applied – crop uptake) over 29 years was strongly negative (Fig. 2) when no P was applied. Extractable P in topsoil decreased about 50%. A surplus of 500 kg ha^{-1} accumulated at an annual application rate of 36 kg ha^{-1}. At this rate no significant change in extractable topsoil P occurred. When a doubled rate was applied the surplus increased to 1500 kg ha^{-1} and the extractable P in the topsoil increased by 50%.

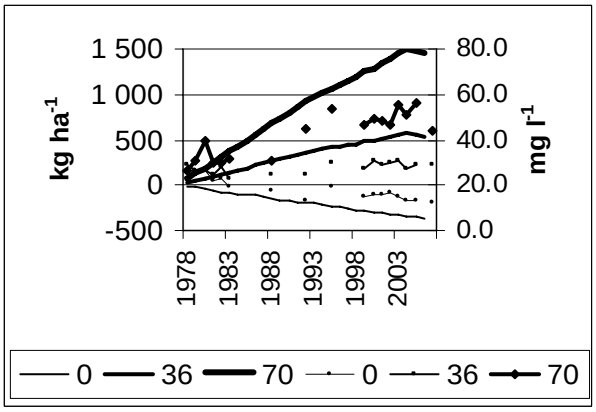

Figure 2. Cumulative P balance (added – uptake, on the left) and P_{Ac} in topsoil (right) at P fertilizer rates of 0, 36, and 70 kg ha^{-1} a^{-1}.

Without K fertilization its balance was strongly negative (Fig. 3). The extractable K in topsoil was reduced by 70%. The annual application rate of 70 kg ha^{-1} coincided with the crop uptake but the reduction in topsoil extractable K was still very clear, about 50%.

In 2005 soil samples were taken from the topsoil (0-25 cm) and two depths of subsoil (25-40 and 40-60 cm) (Table 1). The P concentrations in all the treatments were not detectable below 40 cm. Mixing with topsoil rather than leaching might have caused the increase due to P application in the 25-40 cm soil layer. No evidence of K leaching was detected, so the decrease of K balance in K amended soil remained inexplicable.

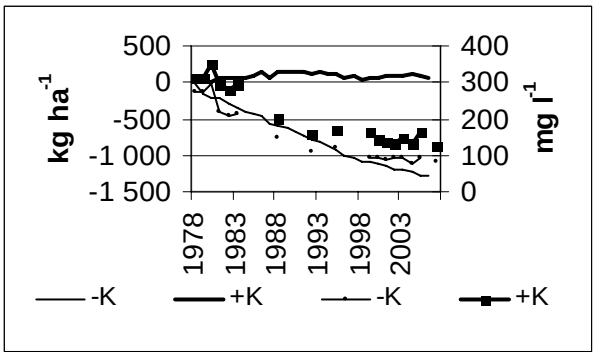

Figure 3. Cumulative K balance (added – uptake, on the left)) and K_{Ac} in topsoil (right) with no K fertilizer (-K) and at the rate of 70 kg ha^{-1} a^{-1} (+K).

Table 1. P_{Ac} and K_{Ac} at different depths in 2005.

Depth, cm	P added, kg ha^{-1} a^{-1}			K added, hg ha^{-1} a^{-1}	
	0	36	70	0	70
0-25	13.2	29.3	56.3	93	166
25-40	7.4	7.8	10.6	113	119
40-60	<3.5	<3.5	<3.5	97	97

Conclusions

Over thirty years a significant depletion of P and K in soil occurred when they were not given in fertilizers. This caused a reduction in crop yield. An abundant P application exceeding the crop uptake very clearly prevented the yield reduction but did not raise the extractable P concentration in the soil. Severe K deficiency did not start to appear until 20 years of growing cereal without fertilizer K. K application compensating for the uptake by the crop did not prevent the decrease of its extractable concentration in this soil, but this decrease did not affect crop yield.

References

Jaakkola, A., Hartikainen, H. & Lemola, R. (1997). Effect of fertilization on soil phosphorus in a long-term field experiment in southern Finland. Agricultural and Food Science in Finland 6: 313-322.