Efficiency of K Fertilization under Different Agroecological Conditions Studied with Maize

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Introduction

Potassium is an essential nutrient for plants. Its physiological and biochemical function in the control of metabolic processes is well-known and established (MARSCHNER, 1986). Among the three macronutrients (N, P, K), potassium is found at the highest concentration in young plants. In some cases, especially in dicotyledons, its concentration exceeds 10% (calculated to dry plant weight). It does not incorporate into organic compounds, it is present in ionic form in the plant cell. Plants producing carbohydrates have a high potassium requirement.

Potassium generally occurs in high concentrations in soils. The total content ranges from 0.2 to 3.3% K, in salt affected soils it can even reach 6%. Exceptions are peat and sandy soils, which generally contain little potassium (STEFANOVITS, 1975). The soils of Hungary generally have a medium potassium status, which is connected with the clay content of soils and with the quality of the dominant clay mineral, too (STEFANOVITS & DOMBOVÁRI, 1994). The K_2O content of soils amounts to 150-170 mg kg^{-1} in Transdanubia (in the western part of the country), but in many cases soils contain less potassium here. In the north–north-west part of the country, 60-80% of the soils contain 150-300 mg K_2O kg^{-1}. In the Great Hungarian Plain, 70% of the soils have a 300 mg ammonium lactate acetic acid extractable, so-called „exchangeable" K_2O content per kg soil (BARANYAI et al., 1987).

To assess the potassium status of our soils, ammonium lactate acetic acid (AL) extraction is widely used. There are, however, literature data according to which the same AL-potassium values measured under different soil conditions do not always satisfy the potassium requirements of plants (SCHWERTMANN, 1993).

In the National Long-Term Fertilization Trials Network, the interrelationship of soil and different fertilizers and their effect on crop yield and crop

quality have been systematically investigated at nine different agro-ecological regions. These experiments provide the opportunity to study the effect of nutrient supply of soils, different fertilizer dose rates and NPK ratios on crop yield and quality under different site conditions (DEBRECZENI & DEBRECZENI, 1994). In this paper experimental data from the Network will be presented. Our aim was to assess the potassium status of Hungarian soils and the effect of potassium fertilization.

Materials and Methods

The National Long-Term Fertilization Trials – forming a unique network in Hungary – have been maintained for 30 years. These trials were set up with winter wheat at nine sites representing different agro-ecological regions of the country in autumn 1967. They were established with uniform fertilization treatments and two different four-year crop rotations. Rotation „A": winter wheat–maize–maize–pea. Rotation „B": winter wheat–maize–maize–winter wheat. In addition, a maize monoculture experiment was started at four sites in the same year (rotation „C").

The experiments include 20 treatments with 4 replications. Treatments: 0, 50, 100, 150 kg N (coded N1, N2, N3); 0, 50, 100 kg P_2O_5 (coded P0, P1, P2); 0, 100 kg K_2O ha^{-1} $year^{-1}$ (coded K0, K1); their different combinations, and an unfertilized control treatment. The effect of K fertilization on maize yield was studied in treatment combinations with increasing N and P doses. The effect of increasing N doses and increasing P doses was investigated on the average of P treatments and in that of K treatments, respectively, with and without K fertilization.

Due to volume restrictions, it is not possible to present the data from all nine sites, only results from four experimental sites – where maize monoculture experiments are also conducted – will be discussed. The first rotations following

Table 1
Main soil characteristics of the experimental sites

Experimental site	Soil type	Clay content %	pH (KCl)	AL-K_2O mg kg^{-1}
Transdanubia:				
Bicsérd	chernozem brown forest soil	33	5.6	206
Iregszemcse	calcareous chernozem soil	22	7.4	150
Great Hungarian Plain:				
Hajdúböszörmény	meadow chernozem	35	6.1	139
Putnok	brown forest soil with clay illuvations	28	4.6	167

the establishment of the trials were neglected from the study, because in our opinion the experimental soils could achieve a balanced nutrient status only by the second rotation cycle. Accordingly, our data refer to the maize plants of the second, third, and fourth rotations „A" and „B", and the results of maize monoculture experiments refer to the same years, too. The main soil characteristics of the experimental sites are given in Table 1.

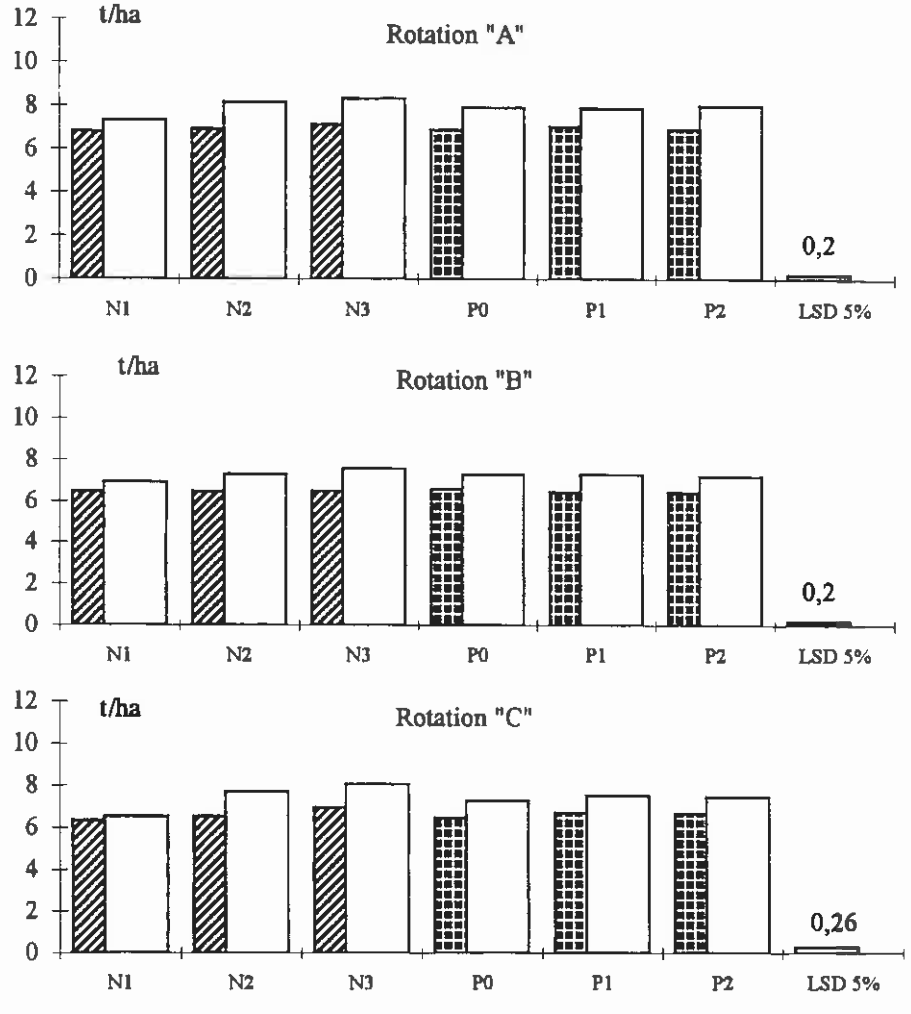

Figure 1
Effect of K fertilization on maize yield (in relation to different N and P levels) on the calcareous chernozem soil (Iregszemcse) (White bars depict K fertilized treatment)

Results and Discussion

Studying the effect of K fertilization on the yield of the test plants (winter wheat, maize, pea) in the network experiments for many years, it was found that maize yield increased to the highest degree. Maize yield increase as an effect of K fertilization of course is not observed uniformly on all soil types of the network. The presented maize yield data – originating from experiments set

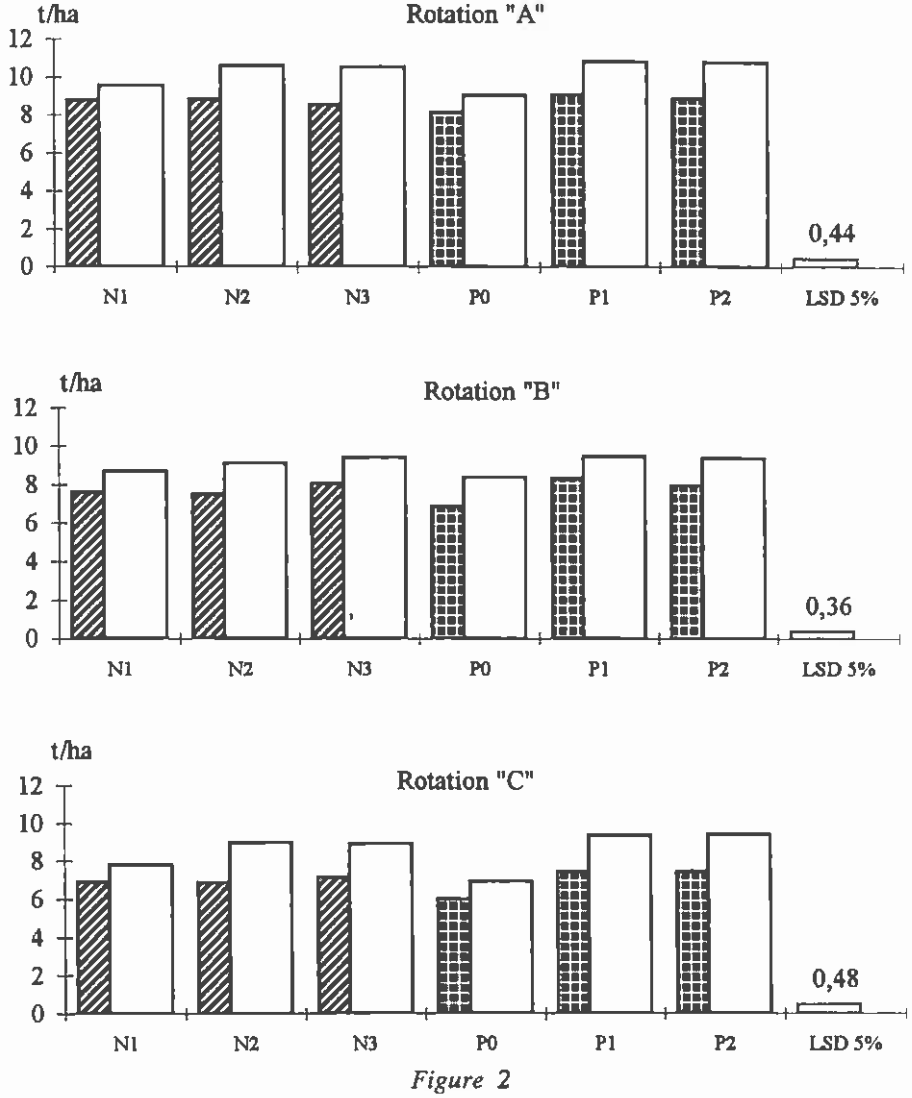

Figure 2

Effect of K fertilization on maize yield (in relation to different N and P levels) on the meadow chernozem soil (Hajdúböszörmény) (White bars: See Figure 1)

up uniformly as regards nutrient supply, crop rotation, cultivars, etc. on four sites with different soil characteristics – reflect the long-term effect of fertilization (1973-1983, Figures 1-4).

On each figure, the first three paired bars present the maize yields gained with increasing N treatments on the average of the P0-P1-P2 treatments. The next three paired bars represent maize yields gained with increasing P treatments on the average of N1-N2-N3 treatments. The white bars indicate the effect of N-P treatment combinations with K fertilization and the striped ones without K.

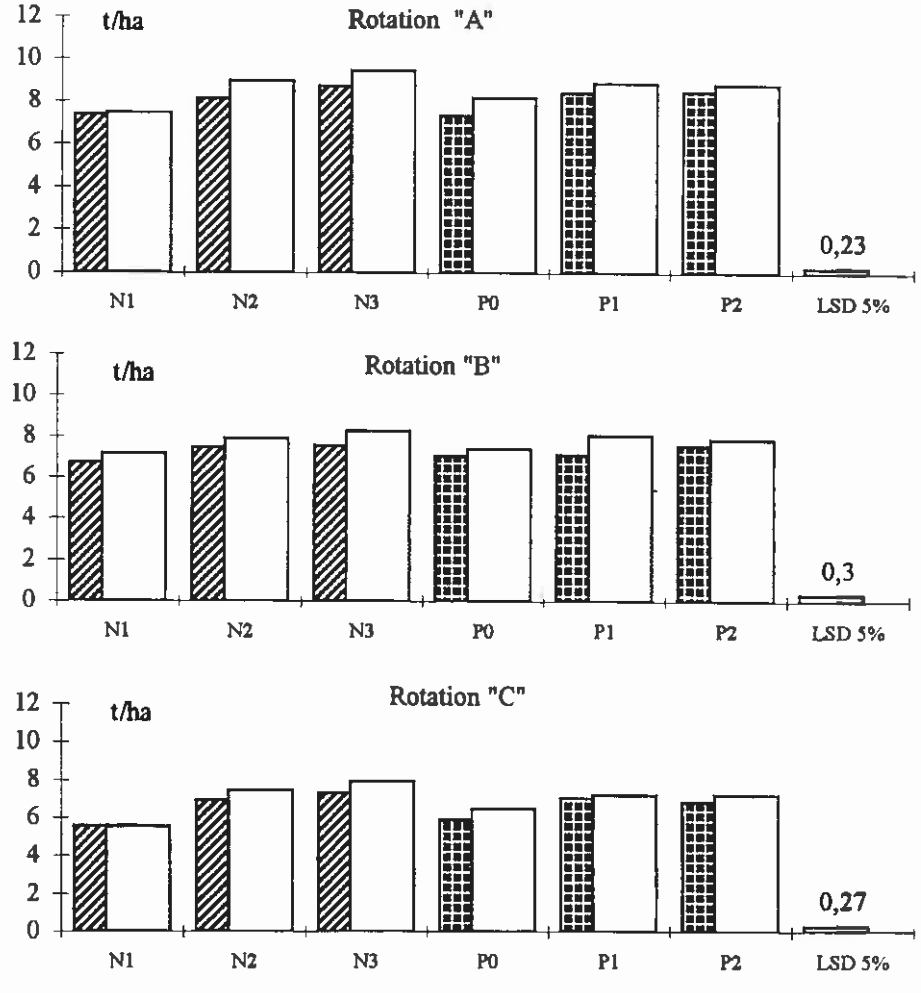

Figure 3
Effect of K fertilization on maize yield (in relation to different N and P levels) on the chernozem brown forest soil (Bicsérd)

K fertilization had a significant yield increasing effect in both rotations, with all treatment combinations, and at both sites (Figures 1 and 2). Yields show a decline in the order of crop rotation A, B, C. With increasing N doses the effect of K fertilization increased on both soil types. The K effect was higher at Hajdúböszörmény than at Iregszemcse and this effect increased with increasing P doses.

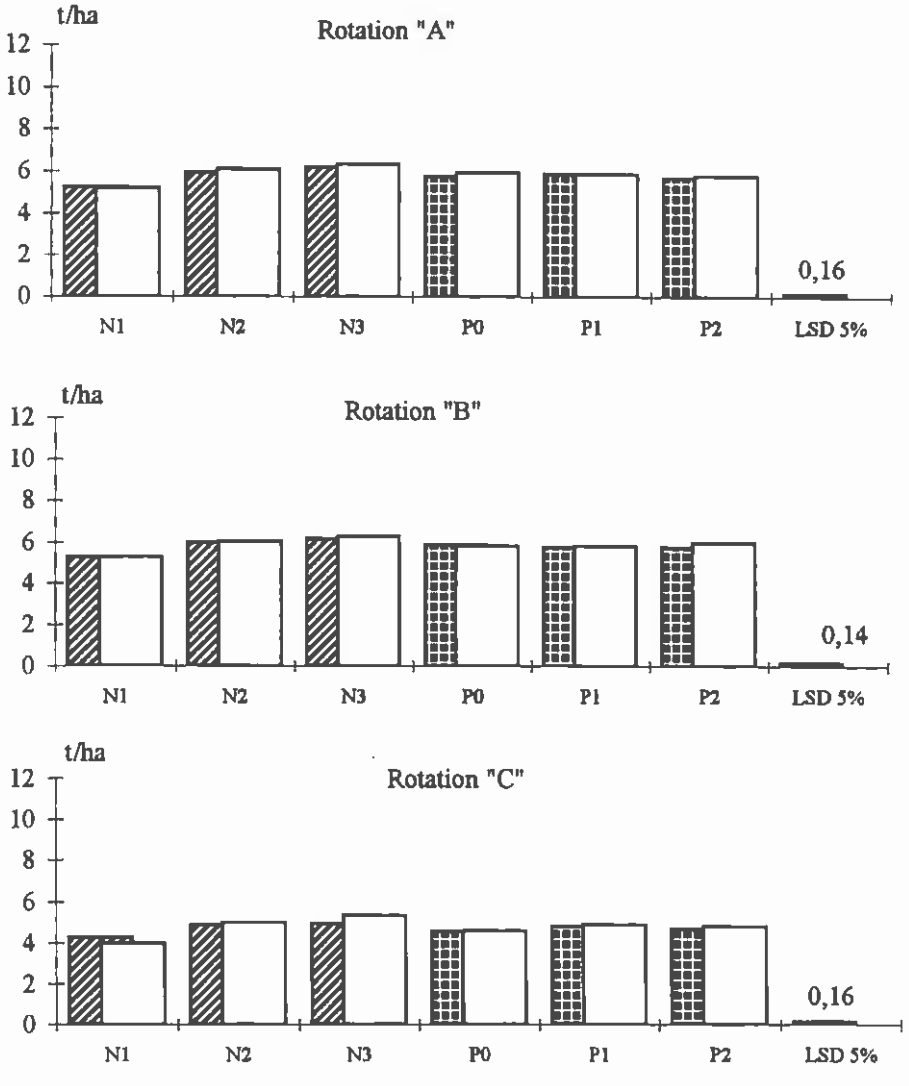

Figure 4
Effect of K fertilization on maize yield (in relation to different N and P levels) on the brown forest soil with clay illuvations (Putnok)

Figures 3 and 4 show maize yields received on the acidic soils of Bicsérd and Putnok. A markedly lower K effect can be seen as compared to that presented in Figures 1 and 2. On the chernozem brown forest soil (Bicsérd) a positive K effect can still be observed with all treatment combinations. The yield increase decreases in the order of crop rotations A, B, C. Increasing N doses decreased the effect of K fertilization to a lesser extent, while phosphorus supply to a higher degree.

At Putnok no yield increase could be detected as an effect of K fertilization. Maize yields gained with N and P treatment combinations were also much lower than the average yields of other sites.

Such great differences in the efficiency of K fertilization cannot be explained on the basis of the clay and AL-K_2O contents of the experimental sites. The highest yield increasing effects of potassium could be detected on experimental soils with the highest and lowest clay content.

The possible explanation of the presented results can be the following. A considerable proportion of the clay content in the meadow chernozem soil rich in clay consists of smectites, which bind K^+ strongly. On such soils, K fertilization is absolutely necessary. On the acidic, brown forest soil with clay illuviations (Putnok), presumably the low exchangable Ca content of the soil is responsible for primarily affecting maize yield favourably and not the potassium supply. The decrease in soil fertility is not caused by nutrient deficiency.

Summary

In Hungary the AL-method – using ammonium lactate acetic acid as extractant – has been widely applied for serial analysis of soil potassium and phosphorus available to plants in the past 30 years. Due to the considerable increase in fertilizer prices and decline in the economic situation, there is a pressing need for cost-effective fertilizer use. Recently this has highlighted the importance of nutrient recommendations based on soil analyses.

Small plot long-term field fertilization experiments are the best means of quantifying the effect or the efficiency of K fertilization. Long-term data sets can reveal the soil types and crops that respond most favourably to the different fertilizer doses and nutrient ratios under differing, long-term balanced soil nutrient levels.

The experimental data of the National Long-term Field Trials reflect the agro-ecological conditions of nine experimental sites representing different soil types of Hungary, so these experiments provide excellent opportunity to study this topic. The trials were set up in 1967 with 20 fertilization treatments including three increasing N and P levels each, two K levels and their different combinations. From the great number of experimental data only those of four sites are shown. Winter wheat, maize, and pea have been grown as test plants. In the experiment selected for presentation, maize had statistically proven re-

sponses to K fertilization. The efficiency of K fertilizer on different soil types, however, shows significant differences, which cannot be completely explained by the results of K analysis gained with the AL-method.

K fertilization had a considerable yield increasing effect on the calcareous and especially on the nearly neutral meadow chernozem. A remarkably smaller K effect could be detected, however, on the strongly acidic chernozem brown forest soil and brown forest soil with clay illuviations; in the latter case there was no K fertilizer effect.

Our studies on the effect and efficiency of K fertilization prove that results cannot be generalized, the fertilizer effects and efficiency have to be quantified by experiments. Under particular soil conditions, routine soil analyses are not sufficient to reveal the reason for the unrealized fertilizer effects, they have to be completed by additional analytical methods. In the investigated case, the unrealized K effect can be attributed to the considerable acidification of the experimental soil. It was not K deficiency that caused the significant maize yield depression and disturbed nutrient responses.

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