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Potassium Supplying Capacity of Soils in Long-term Fertilization Trials Studied in a Pot Experiment

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Introduction

For efficient fertilizer use, detailed information on the nutrient dynamics of different soil types are of primary importance. Reasonable fertilization during cropping systems requires the better understanding of soil nutrient dynamics.

Studies on the relationships between potassium availability and crop responses to the given K rates show the importance of soil type characteristics, especially soil mineralogical properties (GRIMME & NÉMETH, 1979; SPARKS & HUANG, 1985; TISDALE et al., 199; etc.). The availability of soil potassium is controlled by numerous soil and environmental factors, such as moisture, temperature and others (GRIMME et al., 1971; MCLEAN & WATSON, 1985). The potassium content of the soil solution together with easily exchangeable potassium play the major role in plant uptake and are recognized as the plant available amounts (QUÉMENER, 1979; MENGEL & KIRKBY, 1987).

On the other hand, several authors have observed that release from the non-exchangeable potassium reserves may contribute to the potassium supplying capacity of soils (NÉMETH, 1975; MENGEL & WEICHENS, 1979; TISDALE et al., 1993). This varies with soil properties and the amounts of potassium released tend to become available to meet crop requirements. Soil K status determined by various methodologies.(such as EUF) can be correlated with K removal of plants (SINCLAIR, 1982).

Soils in Hungary show considerable differences in clay content and clay mineralogy. Therefore, different levels of available potassium develop even at the same K fertilizer rates (DEBRECZENI & SÁRDI, 1990). The National Long-term Fertilization Trials (NLFT) in Hungary have been continued at 9 experimental sites. These long-term multilocation fertlilization trials provide a good opportunity for studying the potassium dynamics and supplying characteristics of soils.

A pot experiment was carried out under greenhouse conditions to study

– the K supplying capacity of experimental soils depending on soil types and long-term fertilization;

– the differences in the K supplying power of soils, evaluated by the K removal of perennial ryegrass.

Materials and Methods

Soil samples were taken from 9 sites of the National Long-term Fertilization Trials representing various soil types and agroecological regions of Hungary, after 16 years of fertilization. Perennial ryegrass (*Lolium perenne* L.), used as test plant, is known for its ability to utilize potassium from soil reserves (MENGEL & KIRKBY, 1987). 1000 seeds were sown in 1 kg air-dried soil, according to the method of CHAMINADE (1960). Nutrient uptake of ryegrass was studied for 6 months (7 cuts) in the selected fertilizer combinations. Treatments were applied in four replicates.

Selected treatments for this study were as follows:

1. Unfertilized control (Code No. 000).
2. N_5P_3 (250 N and 150 P_2O_5 kg ha^{-1} year^{-1} - treatment code No. 530)
3. $N_5P_3K_1$ (250 N, 150 P_2O_5, 100 K_2O kg ha^{-1} year^{-1} - treatment code No. 531)
4. $N_5P_3K_2$ (250 N, 150 P_2O_5, 200 K_2O kg ha^{-1} year^{-1} - treatment code No. 532)

In the text, simplified labels of these treatment codes are 000, NP, NPK_1 and NPK_2.

Solid P and K fertilizers were mixed into the soil before sowing, N was applied after the cuts (100 mg N per kg soil, applied in ammonium nitrate solution). Soil moisture was kept at 70% WHC by daily watering. Soil types are given according to the FAO Soil Classification System.

The main characteristics of the *experimental soils* are given in Table 1.

Table 1

The main characteristics of the experimental soils

Sampling site	Soil type*	Clay, %	pH (KCl)	Humus, %
1. Bicsérd (BI)	Luvic Phaeosem	33	5.6	1.9
2. Iregszemcse (IR)	Calcaric Phaeosem	22	7.4	2.4
3. Hajdúböszörmény (HB)	Luvic Phaeosem	35	6.1	3.5
4. Karcag (KA)	Luvic Chernozem	37	4.7	2.7
5. Keszthely (KE)	Eutric Cambisol	24	6.3	1.7
6. Kompolt (KO)	Haplic Phaeosem	41	3.9	2.6
7. Mosonmagyaróvár (MO)	Calcaric Fluvisol	12	7.4	1.7
8. Nagyhörcsök (NH)	Calcaric Phaeosem	23	7.2	2.7
9. Putnok (PU)	Ochric Phaeosem	28	4.6	2.0

* Soil types according to the FAO Soil Classification System

Dry matter production and the amounts of potassium taken up by plants (mg K_2O per pot) were calculated for each cut. Values obtained in the NP treatment were plotted as zero values of the x axis. In this way, differences could be expressed as cumulated values and could be compared to those obtained in the NP treatment (i. e. without K application).

Results and Discussion

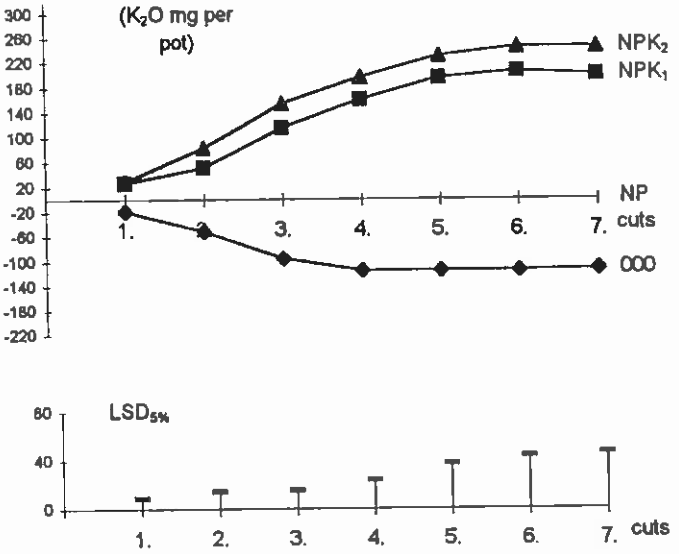
From the results of the experiment, it can be established that significant differences could be observed both in dry matter production and in the amounts of K taken up by plants. Dry matter accumulation showed similar tendencies to potassium uptake of plants during the 6 months (i. e. 7 cuts). In most soils, highly significant differences were obtained in the amounts of K taken up by plants between the NP and the control, NPK_1 or NPK_2 treatments. (Results are summarized in Figure 1.)

Plant analyses showed that K_1 and K_2 potassium rates had markedly increased potassium removal from soils. High potassium removal of plants was observed for chernozems and some brown forest soils with higher clay mineral contents and/or a good soil potassium status resulted by 16 years of K fertilization.

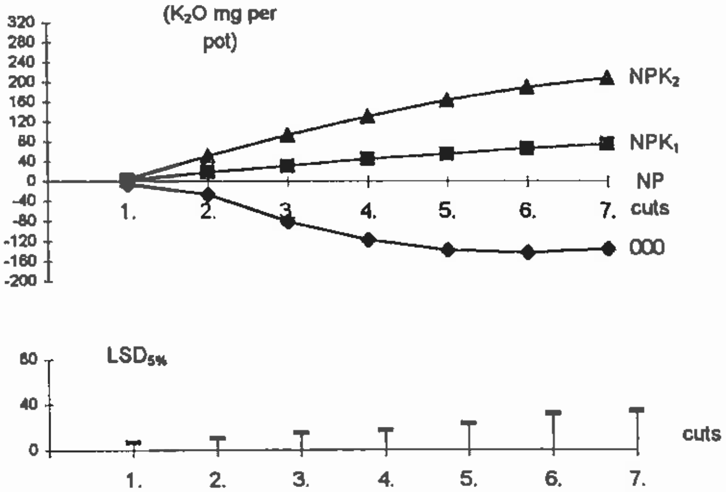
However, it is worth to note that an unexpected good potassium supplying power was observed for the Mosonmagyaróvár (MO) Calcaric Fluvisol, having the lowest clay content among the experimental soils. This was the only site where differences in amounts of K taken up by plants between the NP and control, NPK_1 and NPK_2 treatments, respectively, were the smallest and the values obtained in the unfertilized control even exceeded that of the NP treatment.

Significant differences were found between the curves describing the K uptake of ryegrass in the 000 treatment (unfertilized control) depending on soil type. In the treatments without K, a considerable depletion of potassium supply was observed during the 7 cuts. This was especially remarkable in the curves of Hajdúböszörmény (HB), Kompolt (KO) and Keszthely (KE) soils (Figure 1). Differences in potassium uptake of ryegrass caused by the K_1 and K_2 potassium fertilizer rates were greatest in the Iregszemcse (IR, Calcaric Phaeosem) and Keszthely (KE, Eutric Cambisol) soils. On the other hand, these differences were smallest in the Putnok (PU) acidic, brown forest soil with clay illuviations (Ochric Phaeosem).

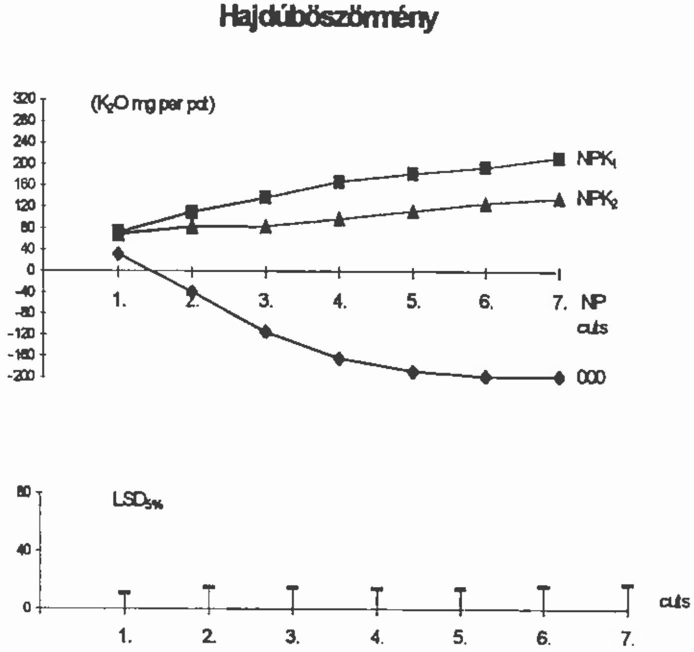
During the 7 cuts, with the continuous potassium removal (i. e. with the depletion of exchangeable K), soils were able to meet the potassium requirement of plants from the non-exchangeable forms. There were marked differences between the experimental soils. On the other hand, these results also showed that perennial ryegrass could enhance nutrition efficiency by taking up potassium ions from the interlayer positions of clay minerals. Further useful information

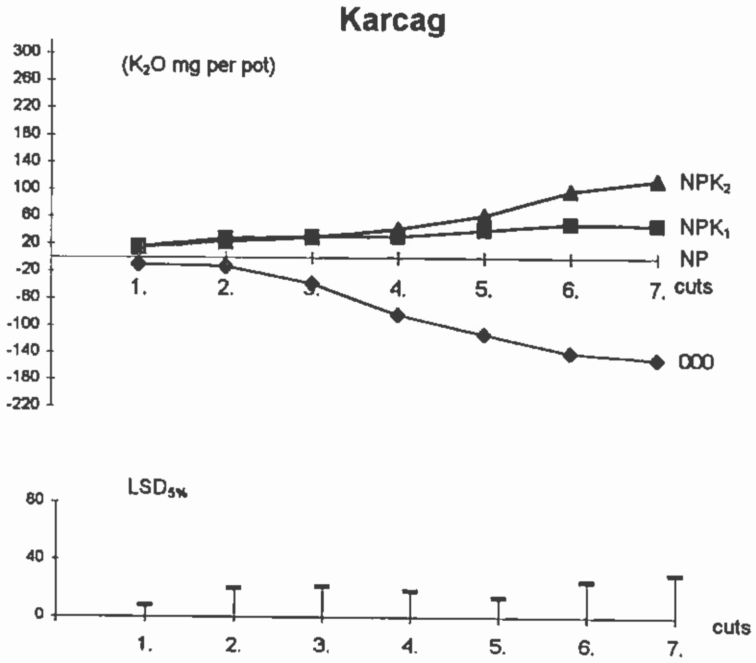


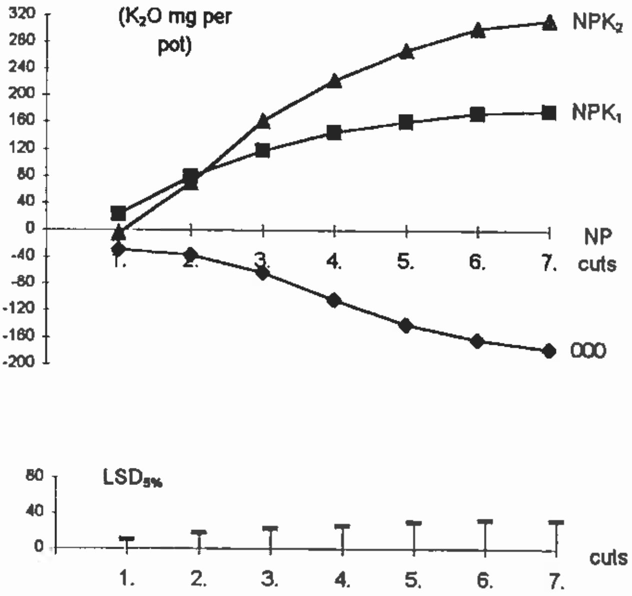
Bicsérd



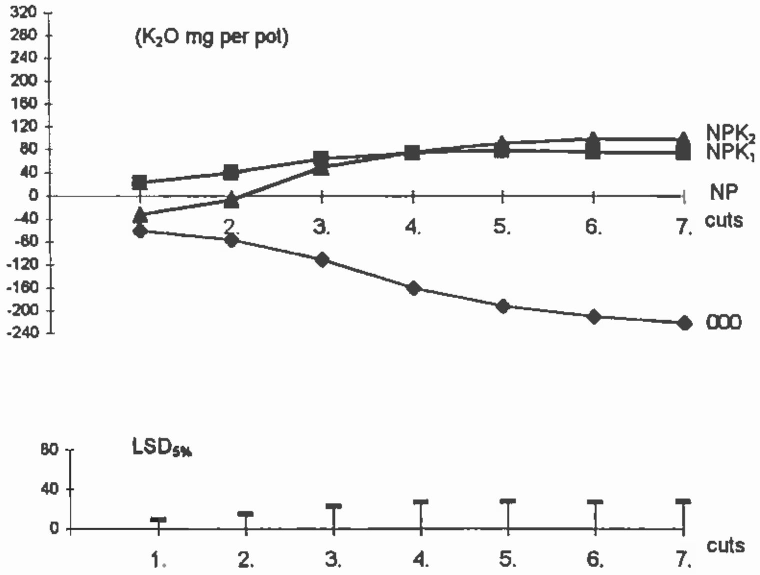
Iregszemcse


Hajdúböszörmény
(K₂O mg per pot)
320
280
240
200
160
120
80
40
0
-40
-80
-120
-160
-200
1.
2.
3.
4.
5.
6.
7.
NPK₁
NPK₂
NP
cuts
000
LSD5%
80
40
0
1.
2.
3.
4.
5.
6.
7.
cuts

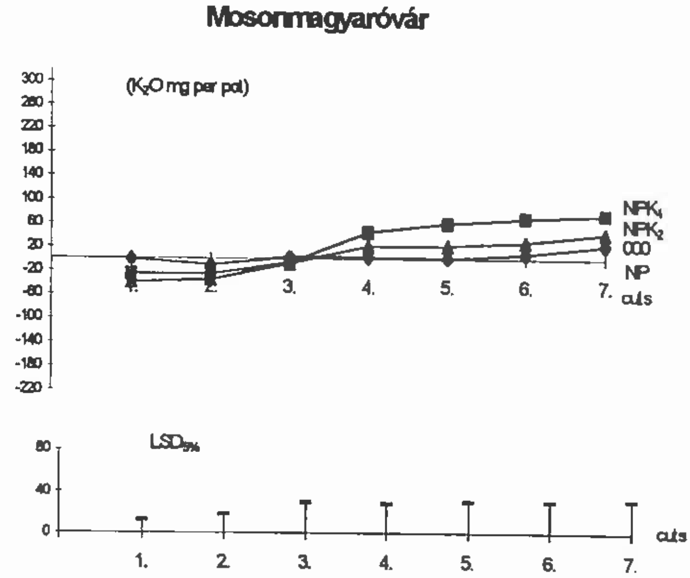

Karcag
(K₂O mg per pot)
300
260
220
180
140
100
60
20
-20
-60
-100
-140
-180
-220
1.
2.
3.
4.
5.
6.
7.
NPK₂
NPK₁
NP
cuts
000
LSD5%
80
40
0
1.
2.
3.
4.
5.
6.
7.
cuts

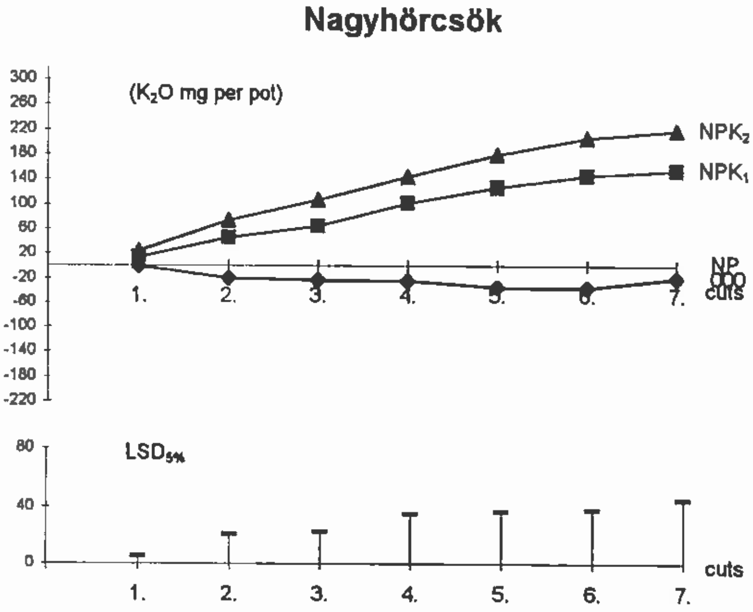


Keszthely



Kompolt


Mosonmagyaróvár
(K₂O mg per pot)
300
260
220
180
140
100
60
20
-20
-60
-100
-140
-180
-220
NPK₁
NPK₂
000
NP
1.
2.
3.
4.
5.
6.
7.
cuts
LSD5%
80
40
0
1.
2.
3.
4.
5.
6.
7.
cuts


Nagyhörcsök
(K₂O mg per pot)
300
260
220
180
140
100
60
20
-20
-60
-100
-140
-180
-220
NPK₂
NPK₁
NP
000
1.
2.
3.
4.
5.
6.
7.
cuts
LSD5%
80
40
0
1.
2.
3.
4.
5.
6.
7.
cuts

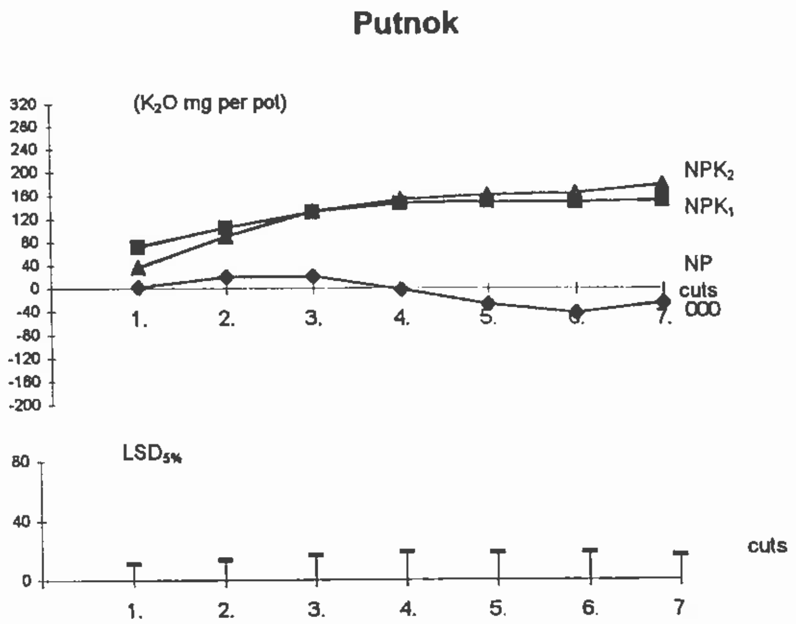


Figure 1

Potassium uptake of ryegrass (cumulated values of 7 cuts) in a pot experiment (Treatments: 000: Unfertilized control; NP: 250 N, 150 P_2O_5; NPK_1: 250 N, 150 P_2O_5, 100 K_2O; NPK_2: 250 N, 150 P_2O_5, 200 K_2O kg ha^{-1} $year^{-1}$)

can be obtained when findings in nutrient supplying characteristics of soils are compared to quantities and proportions of clay minerals.

Conclusions

From the results it can be concluded that:

– Soils varied in their ability to meet the potassium requirement of ryegrass from the non-exchangeable K reserves, which was related not only to the dominant clay minerals (percentages of „K-bearing" clay minerals) but also to other important soil properties (such as amounts of organic colloids or the moisture regime of soils).

– Proportions of the non-exchangeable K fraction in the total amounts of K removed by ryegrass could not be related directly to the clay content and percentages of dominant clay minerals.

Summary

A pot experiment was carried out with soils of fertilization plots from the National Long-term Fertilization Trials Network. These multilocation field trials were established in 1968 with uniform methods to study the effects of increasing NPK fertilizer rates on soil nutrient status at 9 sites. Soil samples were taken after 16 years of fertilization. Perennial ryegrass was grown in pots containing 1 kg soil; moisture was kept at 70% WHC of soils. Treatments were selected from the trials to represent 3 potassium levels: unfertilized control, a K_1 and K_2 application rate (NPK_1 and NPK_2, respectively). The potassium supplying power of soils was studied using the biological testing method during 6 months by taking 7 cuts of ryegrass.

Dry matter production and amounts of potassium taken up by plants (mg K per pot) were calculated for each cut. Values obtained in the NP treatment were plotted as zero values of the x axis. In this way, differences could be expressed as cumulated values and could be compared to those obtained in the NP treatment (i.e. without K application).

From the results of the experiment, it was established that significant differences could be observed in dry matter production and in the amounts of potassium taken up by plants both for soils and treatments. In most soils, highly significant differences were obtained in the amounts of K taken up by plants between the NP and the control, NPK_1 or NPK_2 treatments.

High potassium removal of plants was observed for chernozems and some brown forest soils having higher clay mineral contents and/or a good soil potassium supplying power resulted by the 16 years of K fertilization. However, it is worth noting that an unexpected good potassium supplying power was observed for the MO Calcaric Fluvisol having the lowest clay content among the experimental soils.

With the continuous potassium removal (i. e. with the depletion of exchangeable K) soils were able to meet the potassium requirement of plants from the non-exchangeable forms to a different extent. On the other hand, these results also showed that perennial ryegrass could enhance nutrition efficiency by taking up potassium ions from the interlayer positions of clay minerals. Further useful information can be obtained when findings in nutrient supplying capacities of soils are compared to quantities and proportions of clay minerals.

Acknowledgement

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