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Seria AGROGEOLOGIA ET -CHIMICA N. 63 — Sarja MAA JA LANNOITUS n:o 63

THE DEPENDENCE OF THE PHOSPHORUS UPTAKE OF PLANTS ON THE PROPERTIES OF THE SOIL

Results of a preliminary pot trial

MARTTI SALONEN[1]), INKERI KOSKELA and JORMA KÄHÄRI

SALONEN, M.[1]), KOSKELA, I. & KÄHÄRI, J. 1973 **The depence of the phosphorus uptake of plants on the properties of the soil.** Ann. Agric. Fenn. 12: 161—171.

With oats used as a test plant in pot trial, an investigation was made of the uptake by the plants of, on the one hand, very small and, on the other, very large amounts of phosphorus and the effects on the crops in (1) Gyttja clay containing abundant sesquioxides fixing phosphorus and (2) *Sphagnum* peat free of them.

The largest amount of phosphorus given was clearly favorable to oats growing in Gyttja clay, whereas in the case of oats growing in *Sphagnum* peat as little as 1/8 the amounts of phosphorus produced a crop approximately equivalent in dry matter to that produced by the largest amount. To judge by its effect of retarding the ripening process, the most abundant concentration of phosphorus was on the borderline of harmfulness to the oats grown in the peat.

In the absence of substances capable of fixing phosphorus in the soil, the oats took up as the opportunity offered itself much more phosphorus than the plants actually would have needed — so-called luxury consumption. As far as phosphorus is concerned, this is nearly an unknown phenomenon, the reason being that soils free of substances fixing phosphorus are extremely rare.

Introduction

A modification of the nitrophosphate process was developed some time ago in laboratory of Typpi Oy whereby multinutrient fertilizer can be produced in which the phosphorus almost totally takes a water-soluble form (Fert. Abstr. 1: 1566, 1968). Although it is well-known that the suitability of a phosphorus fertilizer is revealed with fair certainly by its chemical solubility, it is nevertheless necessary in principle, when a new type of fertilizer is in question, to compare it with previously known fertilizers also by using plants. At the Institute of Agricultural Chemistry and Physics, a preliminary comparison was made in a pot trial carried out in the years 1969—1971.

The purpose of the trial was to ascertain the effectiveness of the phosphorus contained

[1]) Retired.

in a new-type multinutrient fertilizer as compared with that in previously known fertilizers. In addition, it was aimed to obtain data on the effects of, on the one hand, very small and, on the other, very large doses of phosphorus as well as the effects in various cases of annual and basal fertilizing.

Phosphorus fertilizers used in the trial

The multinutrient fertilizer under investigation is here designated as mf. The standard phosphorus fertilizer used in the trial was monocalcium phosphate (purissimum), here abbreviated as cp. In addition, an old Finnish specialty, Kotkaphosphate, here designated as kp, was also used in the trial; it is no longer obtainable as such on the market, to be sure, but it is a component of a multinutrient fertilizer for woods on peat soil. The nutrient contents (%) of the fertilizers used in the trial were as follows:

		cp	kp	mf
phosphorus, total	P	24.6	9.9	7.1
» citr. acid sol.	P	—	7.0	6.8
» water-sol.	P	24.6	5.9	6.6
calcium, total	Ca	15.9	25.9	1.4
magnesium, total	Mg	—	0.1	0.04
nitrogen, total	N	—	—	17.8
potassium, total	K	—	—	15.0

DESIGN AND MANAGEMENT OF THE TRIAL

Details of trial, fertilizer treatments, mg/4.5 liters of soil
Gyttja clay: Fertilizer treatments—(1) Phosphorus 0, (2) annually 109 P (marked 3 × 109 or 1 in figures) and (3) at the beginning of the trial 872 P (marked 1 × 872 or 8 in figures), every kind of phosphorus fertilizers. Annual check treatment — Nitrogen 2184 (same as largest dose of mf; ammonium nitrate or mf). Potassium 1843 (as in the foregoing; potassium chloride or mf). The trace element mixture contained B, Cu, Mn, Zn and Mo.
Sphagnum peat: Liming — Calcium carbonate 6, 12 and 24 g per 4.5 liters of soil (marked Lime 1, 2 and 4) at beginning of trial.
Fertilizer treatments — Same as in Gyttja clay.
Annual check treatment — Same as in Gyttja clay, with the addition of magnesium (197 Mg magnesium sulfate) and iron (10 Fe ferric-EDTA).
Replications 1, factorial design.
The proportionate amounts of the main nutrients in the fertilizers were as follows:

	N : P : K	N : P_2O_5 : K_2O
In cases 3 × 109 every year, altogether over a period of 3 years:	1 : 0.05 : 0.84	1 : 0.11 : 1.02
In cases 1 × 872 in the first year of the trial:	1 : 0.40 : 0.84	1 : 0.92 : 1.02
in the next two years:	1 : 0.00 : 0.84	1 : 0.00 : 1.02
altogether during the three years of the trial:	1 : 0.13 : 0.84	1 : 0.31 : 1.02

The test plants used with both types of soil during the entire three-year period were oats, of the Pendek variety, and each time a ripe crop was harvested.

The status of the test soils was kept under observation by carrying out each autumn pH- and conductivity determinations (Figures 1 and 2). The salt content of soil revealed by the conductivity increased substantially, especially in the pots receiving no phosphorus fertilizer; but it was not found to cause any abnormalities in the growth of the plants.

The most important observation made during the years of the trial was the fact that the growth of the oats planted in the pots with *Sphagnum* peat and given abundant phosphorus fertilizer (872 mg/pot) the first year was especially luxuriant at the same time as the development, the ripening process, was conspicuously retarded in comparison with that of the other plants. In the subsequent years, this phenomenon could no longer be observed.

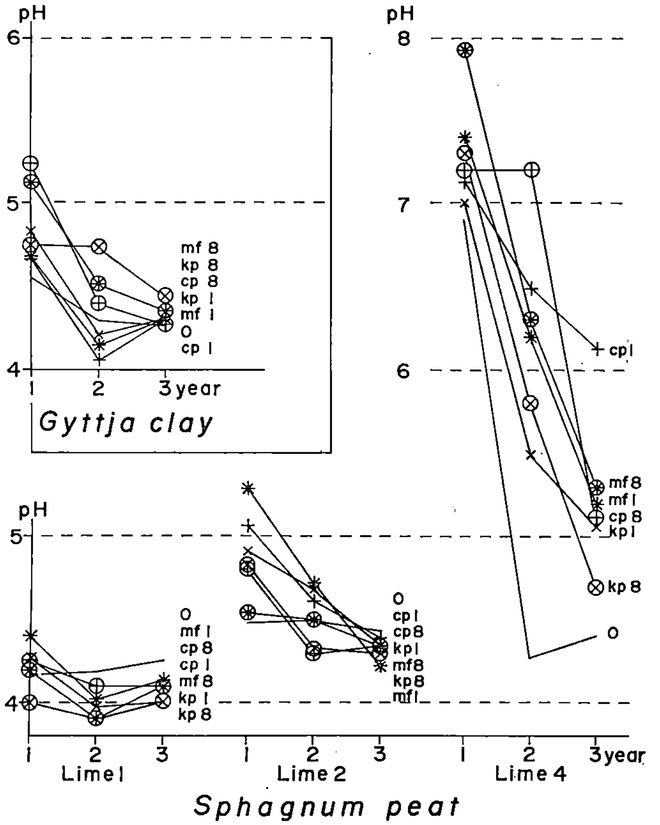

Fig. 1. The pH-values measured in different years (0 = no P, 1 = 3 × 109 P and 8 = 1 × 872 P).

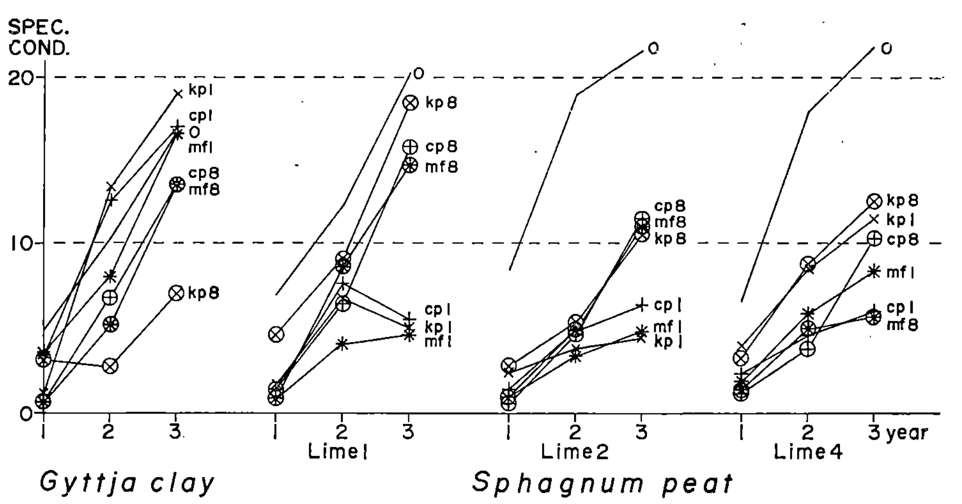

Fig. 2. Specific conductivity value (10 × mmho/cm) in different years.

Presentation of results

The statistical significance of the differences. Since the crops obtained without phosphorus fertilizer are in an entirely different class from the rest, they were omitted from the statistical treatments; only the significance of the differences arrived at with various phosphorus fertilizers were analyzed. The results of the statistical calculations are set forth concisely in Tables 1 and 2.

Table 1. Significances of the differences obtained with different treatments using Gyttja clay.

		Types of phos.	Amounts of phos.	Types × Amounts	Years	Amounts × Years
Grain yield			***		***	*
Straw yield		**	***	**	***	**
Total dry-matter yield		*	***	*	***	**
Moisture content yield at harvesting time					**	*
Nitrogen content	grain		**		***	*
»	straw		***		***	**
Phosphorus content	grain				***	
»	straw				*	**
Potassium content	grain					
»	straw		**		**	*
Calcium content	grain		*		**	*
»	straw				***	
Magnesium content	grain		*			
»	straw					

Table 2. Significances of the differences obtained with different treatments using *Sphagnum* peat.

		Types of phos.	Amounts of phos.	Types x amounts	Liming	Types x liming	Amounts x liming	Types x amounts x liming	Years	Types x years	Amounts x years	Types x amounts x years	Liming x years	Types x liming x years	Amounts x liming x years
Grain yield			*				**		***		***				
Straw yield			***	*	**		**		***		***				
Total dry-matter yield			**		*		**		***		***				
Moisture cont. of yield at harvesting time		*	**						***						
Nitrogen content	grain	**			**				***		***				
»	straw		*		**		*		***		**				
Phosphorus content	grain	**	***				*		***		***				
»	straw	**	***	**	***		***		***	***	***	***	***		***
Potassium content	grain		*						***		**				
»	straw	**	**	*					***		***				
Calcium content	grain				***	*	**		***		**		***		
»	straw	*	**	*	***	**	*	*	***		***		***		
Magnesium content	grain		**		*				***		**		**		
»	straw	*			***	*	**		***	*	***		**		*

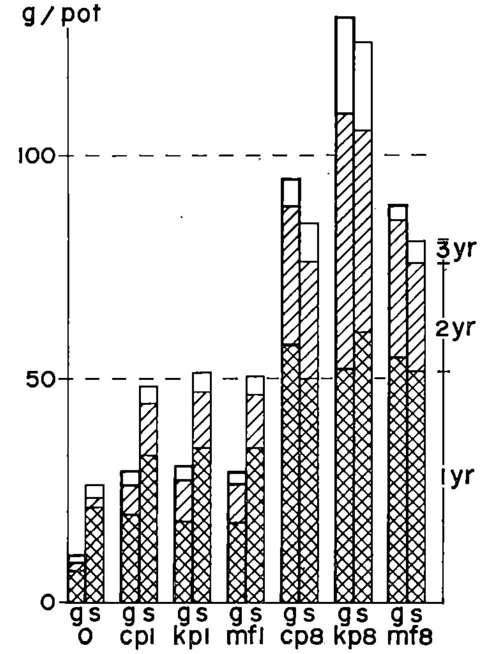

Fig. 3. Gyttja clay: grain and straw yields, dry matter g per pot.

The dry-matter yields are set forth in detail in Figures 3 (Gyttja clay) and 4 (*Sphagnum* peat). As Tables 1 and 2 show, there are no significant differences between the different phosphorus fertilizers with respect to grain yields and with respect to the straw yields only in the case of the plants growing in Gyttja clay. Accordingly, the results obtained with the different types of fertilizer may be combined and attention focussed mainly on the mean values of phosphorus applied. That gives us the values appearing in Table 3.

The nutrient contents of the crops. As Tables 1 and 2 show, the test fertilizers affected the content of the majority of nutrients in the crops. In view of the nature and limited range of the trial, however, not much attention should be paid to differences other than those pertaining to the phosphorus contents.

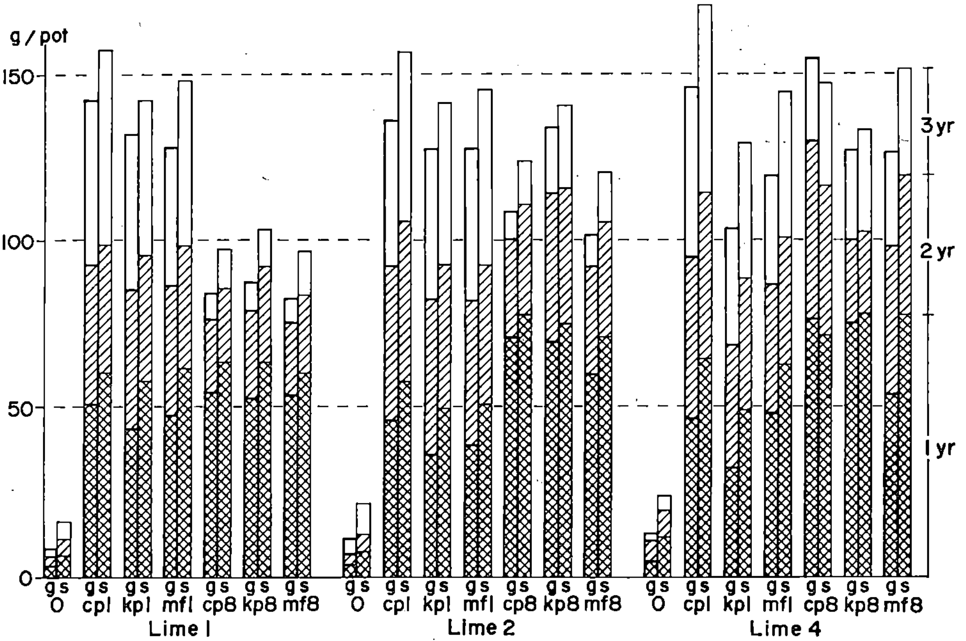

Fig. 4. *Sphagnum* peat: grain and straw yields, dry matter g per pot.

Table 3. Dry-matter yields g per pot.

Liming	P-treatments	Grain 1969	Grain 1970	Grain 1971	Grain Combined	Straw 1969	Straw 1970	Straw 1971	Straw Combined	Grain + straw 1969	Grain + straw 1970	Grain + straw 1971	Grain + straw Combined
					Gyttja clay								
—	3×109	18.3	8.4	3.0	29.7	34.0	12.0	4.0	50.0	52.3	20.4	7.0	79.7
—	1×872	54.7	39.7	10.5	104.9	53.9	31.7	11.2	96.8	108.6	71.4	21.7	201.7
					Sphagnum peat								
1	3×109	47.2	40.7	46.4	134.3	59.7	37.7	52.0	149.4	106.9	78.4	98.4	283.7
1	1×872	53.6	23.7	7.5	84.8	62.1	25.1	12.0	99.2	115.7	48.8	19.5	184.0
2	3×109	39.9	45.5	45.1	130.5	52.2	44.6	51.1	147.9	92.1	90.1	96.2	278.4
2	1×872	66.4	36.0	12.5	114.9	74.3	36.2	17.8	128.2	140.7	72.2	30.3	243.1
4	3×109	41.9	41.1	39.9	122.9	58.4	42.5	47.3	148.2	100.3	83.6	87.2	271.1
4	1×872	68.1	41.3	26.7	136.1	75.5	37.3	31.1	143.9	143.6	78.6	57.8	280.0

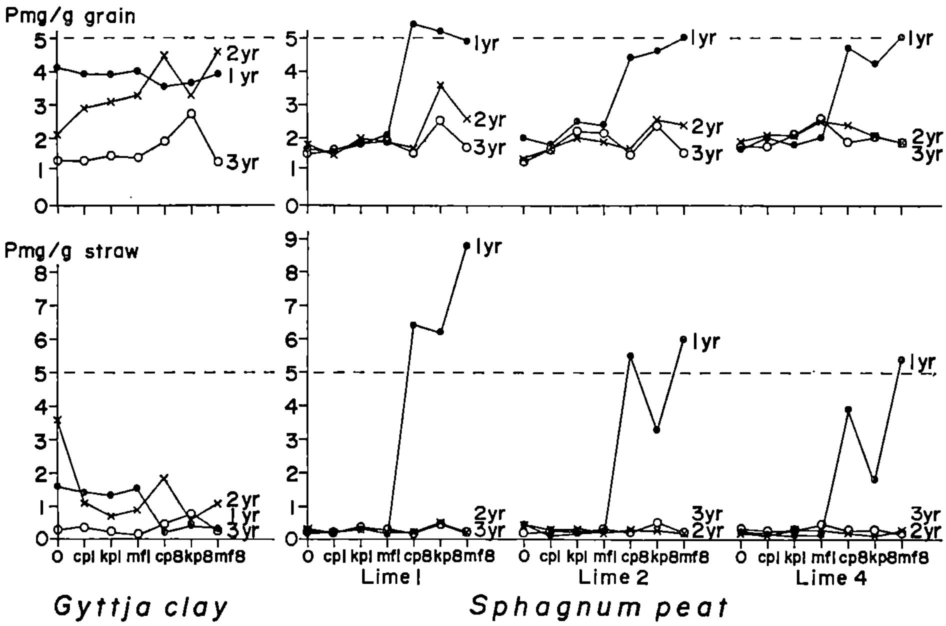

Fig. 5. Phosphorus contents of oats grain and straw, P mg per g of dry matter.

Table 4. Phosphorus contents of grain and straw, P mg per g of dry matter.

Liming	P-treatments	Grain 1969	Grain 1970	Grain 1971	Straw 1969	Straw 1970	Straw 1971
			Gyttja clay				
—	0	4.10	2.15	1.32	1.60	3.58	0.24
—	3×109	3.98	3.10	1.40	1.43	0.89	0.23
—	1×872	3.70	4.12	1.97	0.29	1.18	0.50
			Sphagnum peat				
1	0	1.70	1.81	1.52	0.18	0.35	0.24
1	3×109	1.83	1.81	1.78	0.21	0.23	0.25
1	1×872	5.18	2.61	1.94	7.13	0.31	0.27
2	0	2.00	1.41	1.34	0.43	0.45	0.19
2	3×109	2.23	1.88	2.02	0.17	0.20	0.24
2	1×872	4.67	2.21	1.84	4.93	0.24	0.30
4	0	1.70	1.90	1.72	0.24	0.24	0.29
4	3×109	1.93	2.23	2.14	0.14	0.21	0.28
4	1×872	4.63	2.10	1.91	3.70	0.20	0.22

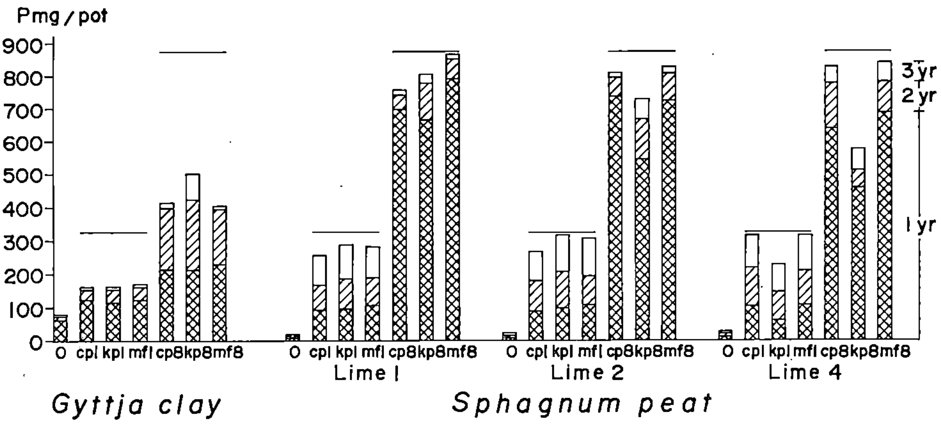

Fig. 6. Amounts of phosphorus contained in crops, P mg per pot. Horizontal line indicates amounts administered in fertilizer application.

Table 5. Phosphorus amounts contained in yields, P mg per pot.

Liming	P-treatments	1969	1970	1971	Combined
		Gyttja clay			
—	3×109	121	39	5	169
—	1×872	219	188	32	439
		Sphagnum peat			
1	3×109	99	82	95	276
1	1×872	718	72	18	808
2	3×109	97	97	102	296
2	1×872	666	90	31	787
4	3×109	90	100	96	286
4	1×872	592	96	58	746

The phosphorus contents of the grain and straw are set forth in detail in Fig. 5, and the mean contents obtained with different amounts in Table 4.

The total amounts of phosphorus taken up by the plants are presented in detail in Fig. 6, which also reveals the quantities of phosphorus given. The mean values are set forth in Table 5.

Table 6 presents the amounts administered in the fertilizer applications and those obtained in the yields with respect to all five of the nutrients investigated. The amounts administered in the check fertilizer applications appear to have been fairly suitable. As far as the magnesium is concerned, exploitation seems to have taken place in the Gyttja clay; but since the clay was relatively rich in magnesium, this circumstance could hardly have had any effect on the growth of the plants (Table 7).

In addition to the elements mentioned, nearly every conceivable determination was made of the trace elements contained in the crops of the first and, to some extent, also the second trial year. The results brought out nothing, however, to explain the differences

Table 6. Amounts of different nutrients administered as fertilizer and appearing in yields, during three trial years mg per pot combined.

Liming	P-treatments	Nitrogen Fer-lizer given	Nitrogen Con-tained in yields	Phosphorus Fer-tilizer given	Phosphorus Con-tained in yields	Potassium Fer-tilizer given	Potassium Con-tained in yields	Calcium Fer-tilizer given	Calcium Con-tained in yields	Magnesium Fer-tilizer given	Magnesium Con-tained in yields
					Gyttja clay						
—	0	6552	799	0	79	5329	1161	0	105	0	79
—	3×109	6552	1808	327	164	5329	2122	376	178	1	155
—	1×872	6552	3536	872	440	5329	4713	1004	393	3	376
					Sphagnum peat						
1	0	6552	235	0	18	5329	326	2400	79	591	27
1	3×109	6552	5143	327	276	5329	4343	2776	469	592	345
1	1×872	6552	3218	872	808	5329	3187	3404	616	594	333
2	0	6552	701	0	24	5329	608	4800	71	591	37
2	3×109	6552	5038	327	295	5329	4288	5776	816	592	428
2	1×872	6552	4088	872	787	5329	3677	5804	998	594	455
4	0	6552	459	0	28	5329	583	9600	106	591	47
4	3×109	6552	4466	327	286	5329	4703	9976	1234	592	452
4	1×872	6552	4436	872	745	5329	4413	10604	1455	594	477

Table 7. Analytical data on the soils used in the trial.

Liming	P-treatments	pH H_2O	Conductivity	P (mg per liter of soil)	K (mg per liter of soil)	Ca (mg per liter of soil)	Mg (mg per liter of soil)
			Gyttja clay — before the trial				
—	—	5.1	0.9	6.3	370	1200	559
			— autumn 1971				
—	0	4.3	16.6	6.9	870	1000	428
—	3×109	4.3	17.6	9.3	760	1150	444
—	1×872	4.4	11.3	10.2	438	1215	437
			Sphagnum peat — before the trial				
—	—	3.5	0.8	3.2	40	200	40
			— autumn 1971				
1	0	4.3	20.2	1.7	880	600	170
1	3×109	4.1	5.1	3.9	220	733	124
1	1×872	4.1	16.3	2.1	600	733	124
2	0	4.4	13.1	1.7	900	900	165
2	3×109	4.3	5.1	3.5	176	1058	92
2	1×872	4.3	11.1	2.9	380	1050	102
4	0	4.4	15.3	2.0	900	1500	168
4	3×109	5.5	8.5	4.0	103	1733	91
4	1×872	5.0	9.4	5.1	202	1675	91

in the yields; hence these determinations were not pursued further and the results of the ones made are not presented in this connection.

The results of the soil analyses are given in Table 7. These figures likewise support the view that the sole factor limiting the yields was the phosphorus supply. The figures also prove that the phosphorus dose in the *Sphagnum* peat was used up quite completely, for nearly all the phosphorus in *Sphagnum* peat dissolves even under treatment as mild as extraction with acid (pH 4.65) ammonium acetate, whereby the soil analyses were performed.

Discussion of the results

The amounts of phosphorus contained in crops (Fig. 6) might probably be regarded as the best evidence of the value of a phosphorus contained in multinutrient fertilizer of the new type (mf) appears to be altogether on a par with monocalcium phosphate (cp) — in very acid soil even somewhat more effective. Kotkaphosphate (kp) appears to be particularly effective when used in Gyttja clay; but in results achieved with *Sphagnum* peat, too, there is to be observed the consistency that its suitability improves with increasing acidity of the soil. Although nuances like this appear in the results, the comparison of the effects of the phosphorus in different kinds of fertilizer remained uncertain (Tables 1 and 2), whereas some other features brought out by the investigation could be satisfactorily corroborated — specifically, the varying effects of small annual and large basal applications of fertilizers in different soils.

The Gyttja clay used in the trial represents a type of soil containing an abundance of substances effectively fixing phosphates, above all, so-called sesquioxides. From such soil it is difficult for plants to obtain native phosphorus, besides which phosphorus administered in fertilizer, too, rapidly turns into a form hard for plants to utilize. In pure *Sphagnum* peat, on the other hand, there are no sesquioxides or other substances that fix phosphates. Thus the very slight amount of phosphorus naturally present in *Sphagnum* peat exists totally in a water-soluble form, and also phosphorus added to the soil, remains soluble — and even a difficult-soluble form becomes soluble (SALONEN 1968). These circumstances should suffice to explain the difference between Gyttja clay and *Sphagnum* peat with respect to the uptake of phosphorus by plants growing in them.

An unexpected finding was that plants can take up phosphorus to such an extent over and above their need — nearly to an injurious extent — as occurred in this trial in the case of the *Sphagnum* peat. It is possible to speak of the true "luxury consumption" of phosphorus, in view of the fact that as little as 1/8 produced the same yield (the first year). That the amounts of phosphorus were excessive from the standpoint of the plants themselves became evident in that, for instance, they caused disturbances in the growth rhythm; this was noted in the retarted rate of ripening. An unnatural increase in the phosphorus content was observed only in the first year of the trial. Fig. 6 and Table 5 show that later it was no longer possible because the excess phosphorus had been consumed. In the case of the plants grown in Gyttja clay, again, even a large excess of fertilizer did not increase the phosphorus content of the plants very much (Table 4 and Fig. 5). This observation supports the prevailing view of the response of plants to abundant phosphorus in the soil.

It is well known that the contents of various substances, including phosphorus, in grain remain fairly stabile. In the present trial, however, abundant application of phosphorus had the effect of even doubling the phosphorus content of the grain of plants grown in *Sphagnum* peat the first year. The largest increase in the phosphorus content took place, however, in the straw, in which it was measured to be as much as from 20 to 30 times the values registered after scanty fertilization with phosphorus. Only slight differences could be detected in the outward appearance of the plants.

In the literature, we could find only scanty data on excessive uptake of phosphorus by plants. SCHARRER et al. (1952), using quartz sand in a pot trial, raised the phosphorus content of oat straw nearly as high as the value measured in the plants grown in *Sphagnum* peat in the present experiment. Cases of actually injurious effects from excessive phosphorus have been reported by ROSSITER (1952), BHATTI and LONERAGAN (1970) and others. BUCHNER (1952) expressed the view that plants are apt to register an excessive phosphorus content especially in the event that there is a large excess of this element in the soil in comparison with other nutrients. The same view has been taken emphatically by Rossiter. In the present trial, however, the fertilizer did not contain any corresponding excess of phosphorus (p. 162).

With reference to the luxury consumption of phosphorus, it has been demonstrated (KAILA 1958, KAILA and HÄNNINEN 1960) that the phosphorus contents of red clover and timothy tend to vary according to the abundance of available phosphorus, the variations occuring mainly on the part of the inorganic phosphorus, the organic phosphorus remaining on nearly the same level.

Among the nutrients needed by plants in large amounts, potassium has long been known as a substance that can be taken up by plants to the point of luxury consumption, meaning that plants consume more of it than they really need. The fact that this phenomenon is hardly known in connection with phosphorus does not appear to be due to any regulatory process undergone by the plants themselves, for the plant is liable, under suitable circumstances, to consume more of the nutrient than it requires — even in amounts injurious to itself. It is due to the strong retention by normal agricultural soil of phosphates that such an occurence has hardly ever been noticed.

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SELOSTUS

Kasvien fosforin oton riippuvaisuus kasvualustan ominaisuuksista

Alustavan luonteisen astiakokeen tuloksia

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Maatalouden tutkimuskeskus, Maanviljelyskemian ja -fysiikan laitos, Tikkurila

Typpi Oy:ssä kehitetyn uudentyyppisen moniravinteisen lannoitteen (Fert. Abstr. 1: 1566, 1968) fosforin tehon vertailemiseksi tunnettujen lannoitteiden vastaavaan (monokalsiumfosfaatti = puhdas kemikalio ja kotkafosfaatti) oli Maanviljelyskemian ja -fysiikan laitoksessa vuosina 1969—71 käynnissä astiakoe. Uuden lannoitteen fosfori osoittautui samanarvoiseksi kuin tunnettujen lannoitteiden fosfori. Lisäksi tuli esille muita puolia, joilla voi olla yleistä mielenkiintoa.

Erittäin korostettuna tuli esille kasvien fosforin saannin riippuvaisuus kasvualustan ominaisuuksista. Koemaina oli toisaalta runsaasti fosforia pidättäviä rauta- ja aluminiumyhdisteitä sisältävä liejusavi ja toisaalta niistä, samoin kuin muistakin fosforia pidättävistä aineista, vapaa raaka rahkaturve. Koekasvina käytetty kaura voi liejusavesta irroittaa vain niukasti lannoituksessa annettua fosforia, kun taas rahkaturpeesta se voi ottaa runsaankin useiden vuosien ajaksi varastolannoitukseksi tarkoitetun fosforimäärän jo ensimmäisenä vuotena hyvin tarkoin (taulukot 5 ja 6, kuva 6).

Toinen kiintoisa tulos on se, että sopivissa oloissa kaura on voinut ottaa fosforia enemmän kuin se olisi tarvinnut (ns. luksuskulutus). Taulukosta 4 ja kuvasta 5 nähdään, että rahkaturpeessa kasvaneessa kaurassa on sekä jyvien että varsinkin olkien fosforipitoisuus voinut nousta erittäin korkeaksi. Suuremmalla fosforilannoituksella onkin fosforin saannin runsaus ollut ensimmäisenä koevuotena jo vahingollisen rajoilla. Silloin kauran kasvu oli epänormaalisen rehevää ja tuleentuminen myöhästyi.

Kasvien yli tarpeen oleva fosforin otto on ollut lähes tuntematon ilmiö. Esim. kirjallisuudesta löytyy siitä vain harvoja mainintoja. Niissä on liiallisella fosforilla ollut useimmiten suoranainen myrkkyvaikutus. Nyt esitetyt koetulokset osoittavat, että yli tarpeen olevaa fosforin ottoa voi ilmetä, jos annetaan runsas fosforilannoitus ja kasvualustasta puuttuu fosforin pidätyskyky.

ANNALES AGRICULTURAE FENNIAE, VOL. 12: 172—184 (1973)

Seria AGROGEOLOGIA ET -CHIMICA N. 64 — Sarja MAA JA LANNOITUS n:o 64

EFFECTS OF HEAVY NITROGEN DRESSINGS UPON RELEASE OF POTASSIUM FROM SOILS CROPPED WITH LEY GRASSES

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JOY, P., LAKANEN, E. (†) & SILLANPÄÄ, M. 1973. **Effects of heavy nitrogen dressings upon release of potassium from soils cropped with ley grasses.** Ann. Agric. Fenn. 12:172—184.

Three year experiments on the effects of N fertilization (0—600 kg N/ha/yr) on the K uptake by two crops (fescue and cocksfoot) and on the changes in K status of the soils were carried out at 14 sites in Finland.

For both plants, K uptake was maximal at a little over 450 kg N/ha/year. At this level fescue took up about 4 times, and cocksfoot 4 ½ times as much potassium as at the control level.

For the whole material (both plants, all soils) the three year maximum mean net K uptake (at the 450 kg N/ha/yr level) was 520 kg K/ha. This is nearly twice as high as the corresponding mean loss in HCl-extractable soil K or nearly four times as high as the respective fall in exchangeable K. Exchangeable K is continually being replaced by reserve K and the uptake excess must come either from soil depths below 20 cm or from soil K reserves not extractable by HCl. The present results do not show which of these mechanisms plays the main role.

Long-term effects of N fertilization on soil K depend largely on the initial potassium content of the soil. The three year experiments show that soils initially low in potassium cannot support high rates of K uptake for any longer under these unbalanced conditions of fertilization.

Introduction

In field trials started at several experimental stations in Finland in 1966, potassium uptake by fescue and cocksfoot increased with increasing rate of nitrogen fertilization, upto 450 kgN/ha. Even at rates much lower than this, the three year uptake of potassium was often considerably greater than the fall in readily extractable potassium, plus fertilizer dressings. Also in Finland, HUOKUNA (1968) applied nitrogen to meadow fescue-timothy swards at the rates of 100 and 300 kg/ha. He found that the mean second and third year uptake of potassium was 42 % greater at the higher rate than at the lower.

In British field trials, HOPPER and CLEMENT (1967) showed that a ryegrass sward dressed with 314 kg N/ha/year took up more potassium in early years than did a ryegrass-clover stand with no nitrogen. This gap, however, tended to close in later years. In another trial, reserves of exhangeable potassium were built up to a high level by 4 years' grazing + 125 kg K/ha/year. The soil was then ploughed, and cropped by cut grass receiving 314 kg N/ha. After only one year the soil contained less exchangeable K than at the beginning of the experiment. From this, these authors conclude that crop growth, yield and nitrogen supply must be taken into account when relating long-term crop response or uptake to potassium status of the soil.

It should be mentioned that behaviour in this respect is likely to vary from crop to crop. According to SALMON (1965), ryegrass is a more efficient extractor of non-exchangeable potassium than many other plants. COOKE (1967) also mentions this difference between the abilities of various crops to take up potassium from sources not readily available.

The main aim of the present work is to study the importance of nitrogen supply in potassium uptake by fescue and cocksfoot*) for 14 Finnish sites and over a three year period. A secondary aim is to relate the progressive dependence of potassium uptake upon non-exchangeable sources of potassium, with increasing nitrogen level.

Evidence of non-exchangeable potassium uptake by various plants used in pot experiments is not lacking. Many authors, among them TABATABAI and HANWAY (1969), HOAGLAND and MARTIN (1933), CHANDLER, PEECH and CHANG (1945), GHOLSTON and HOOVER (1948), REITEMEIER (1951), WEBER and CALDWELL (1965) agree that on cropping to exhaustion, exchangeable potassium first falls rapidly, then more slowly asymptotes to a »minimal» level which tends to be constant for a given soil. The readily exchangeable potassium having been exhausted the plant is more dependent upon non-exchangeable potassium and tends to draw more from non-exchangeable sources.

However, ARNOLD and CLOSE (1961) point out that there is a time lag between release of exchangeable and release of non-exchangeable potassium. Thus, rates amounting to starvation levels in pot-grown plants may be quite adequate for plants growing under less intensive conditions in the field. REITEMEIER has mentioned that these »minimal» exchangeable potassium levels are not so likely to be reached in the field as in small containers. HOPPER and CLEMENT point out that in field conditions both release of non-exchangeable potassium and uptake below 15 cm depth may have supplied the bulk of potassium taken up.

In this study the dependence of potassium uptake upon nitrogen supply and relative uptake from exchangeable and reserve supplies in relation to nitrogen supply will be discussed.

Materials and methods

The layout at each site consisted of 2 crop species; fescue and cocksfoot. Timothy was substituted for cocksfoot at the two northernmost sites. Five nitrogen treatments were used; 0, 150, 300, 450 and 600 kg N/ha/year, and each treatment was replicated four times. Thus at each site there were 2 species × 5 treatments × 4 replicates = 40 plots. Each plot received potassium fertilizer at the rate of 100 kg K/ha/year, as well as 500 kg of superphosphate (8,7 % P)/ha/year.

The grass ley was sown in the late summer of 1966, after which the first soil sampling was made. These samples represent the soil depth from 0—20 cm. Three or four harvests were cut during each of the years 1967, -68

*) Timothy at the two northernmost sites.

Table 1. Properties of soils at the 14 experiment sites.

Site		Soil group and type	Particle size distribution, % <0.002	0.002 –0.02	0.02 –0.2	0.2 –2 mm	C % 1966	C % 1969	N % 1966	N % 1969	Extractable K NH$_4$Ac kg/ha	Extractable K HCl kg/ha	Total K kg/ha	Relations between three K indices: NH$_4$Ac Ex. K / HCl Ex. K %	NH$_4$Ac Ex. K / Total K %	HCl Ex. K / Total K %
1. KVL	Dept. of Plant Husb. Tikkurila	*Fine miner. soils* Sandy clay	35.4	36.3	19.5	8.8	3.10	3.44	0.24	0.26	550	3402	48760	16.2	1.13	6.98
2. LOU	S.W. Finl. Exp. Sta. Mietoinen	Heavy clay	62.7	25.0	9.6	2.7	3.17	3.59	0.26	0.28	698	7084	60140	9.85	1.16	11.8
3. KAR	Karjala Exp. Sta. Anjala	Silty clay	40.9	41.8	12.7	4.6	3.05	2.89	0.20	0.21	398	3150	52920	12.6	0.752	5.95
4. SAT	Satakunta Exp. Sta. Peipohja	Sandy clay	44.2	34.0	19.5	2.3	3.83	3.86	0.27	0.28	426	3698	51080	11.5	0.830	7.24
5. EPO	S. Pohjanmaa Exp. Sta. Ylistaro	Clayey silt	36.4	54.5	7.0	2.1	6.25	6.38	0.41	0.44	522	3172	36780	16.5	1.42	8.62
6. KSU	Centr. Finland Exp. Sta. Laukaa	Silt	19.2	53.3	25.2	2.0	2.52	2.64	0.17	0.19	166	2410	48040	6.89	0.345	5.02
	Means, Fine mineral soils		39.8	40.8	15.6	3.8	3.65	3.80	0.26	0.28	460	3820	49634	12.0	0.927	7.70
7. HÄM	Häme Exp. Sta. Pälkäne	*Coarse miner. soils* Finesand	20.2	28.6	31.2	20.0	3.30	3.19	0.19	0.21	338	5052	49580	6.69	0.682	10.2
8. TOH	Peat Soc. Exp. Sta. Tohmajärvi	Finesand	4.2	11.5	79.6	4.7	3.39	3.48	0.22	0.23	266	1238	24860	21.5	1.07	4.98
9. KPO	C. Pohjanmaa Exp. Sta. Laitala	Finesand	11.7	36.0	49.2	3.1	5.59	6.01	0.28	0.33	240	1350	39620	17.8	0.606	3.41
10. LAI	Pasture Exp. Sta. Mouhijärvi	Finesand	12.6	22.2	57.1	8.1	2.69	2.62	0.20	0.21	470	5162	49100	9.10	0.957	10.5
11. ESA	S. Savo Exp. Sta. Mikkeli	Finesand	3.8	6.8	53.7	35.7	4.00	4.09	0.27	0.28	186	1266	34760	14.7	0.535	3.64
12. PPO	N. Pohjanmaa Exp. Sta. Ruukki	Finesand	19.3	26.3	44.6	9.8	4.67	4.75	0.24	0.27	166	2174	45580	7.63	0.364	4.77
	Means, Coarse mineral soils		12.0	21.9	52.6	13.6	3.94	4.02	0.23	0.25	278	2708	40592	10.3	0.685	6.67
13. LET	Peat Soc. Exp. Sta. Leteensuo	*Peat soils* Sphagnum peat					22.3	22.6	0.70	0.79	222	2102	8380	10.6	2.65	25.1
14. PRP	Arctic Circle Exp. Sta. Rovaniemi	Carex peat					43.3		2.30		130	162	516	80.2	25.2	31.4
	Means, Peat soils						32.8		1.50		176	1132	4448	15.5	3.96	25.4
	Means, Mineral soils						3.80	3.91	0.25	0.27	369	3264	45113	11.3	0.818	7.24

and -69. In the meantime, all the plots had received potassium totalling 300 kg K/ha. After the 1969 harvests, the second series of soil samples was taken.

A rather arbitrary grouping of the 12 mineral soils into two texture classes allowed statistical analyses of results obtained for both fine and coarse soil groups. Data on soil properties are given in Table 1.

G r o s s   p o t a s s i u m   u p t a k e by the leys was determined on the basis of dry matter yields and potassium contents of representative samples chosen from the bulk of each harvest. Because the samples were of pure fescue or cocksfoot excluding weeds, the yields given here underestimate the actual yields. However, botanical analyses indicate that this error amount at most to only a few percent.

Net potassium uptake is gross uptake minus 300 kg K/ha put back as fertilizer over the three year period.

Exchangeable potassium was determined on both 1966 and 1969 samples, for each of the 5 treatments and the 2 crop species grown at each site. Samples from individual replicates (40 per site) were extracted according to VUORINEN and MÄKITIE (1955), and equal volumes of extract from the 4 replicates representing a treatment bulked. Owing to widely varying soil volume weights, the results are expressed on a volume basis.

Reserve potassium has been estimated using various methods (e.g. WOOD and DETURK 1941, GARMAN 1957, KAILA 1967). KAILA's method, employing 1 N HCl at 50°C for 20 hr, was used in this study. Exchangeable K (see above) is subtracted from HCl-extractable K to give reserve K.

Total potassium was determined on bulked 1966 soil samples: 0.25 g of soil, ignited at 450°C overnight was digested with 5 ml of 48 % HF and 0.5 ml of 70 % $HClO_4$. The $HClO_4$ addition and subsequent expulsion was repeated. The residue was taken up in dilute HCl and potassium determined in this solution.

To obtain commensurable dimensions for K fertilization, K uptake and soil K, also the latter is given in kilograms per hectare (One hectare is considered as a hectare plough layer, 20 cm in depth, equalling 2 million liters. Thus, 1 kg/ha = 0.5 mg/litre of soil).

The figures for K uptake, fertilization and changes in soil exchangeable and reserve K were totalled for the three years and are given in Table 2 as means of the four replicates in each treatment.

Results and discussion

Relative amounts of exchangeable, acid-extractable and total potassium in bulked 1966 soil samples appear from the data in Table 1. The weighted mean percentages given in the last three columns show that for both mineral soil groups, NH_4Ac-extractable: HCl-extractable: total K occur very roughly in the ratio 1 : 10 : 100. There is some varia-

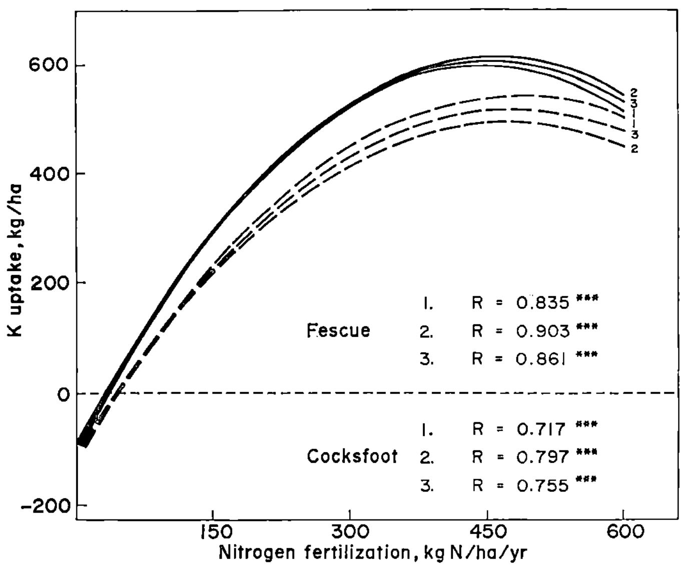

Fig. 1. The effect of nitrogen fertilization upon net potassium uptake by fescue (broken lines) and cocksfoot (solid lines) on fine (1), coarse (2) and all (3) mineral soils. Significance levels 99.9***, 99** and 95* per cent.

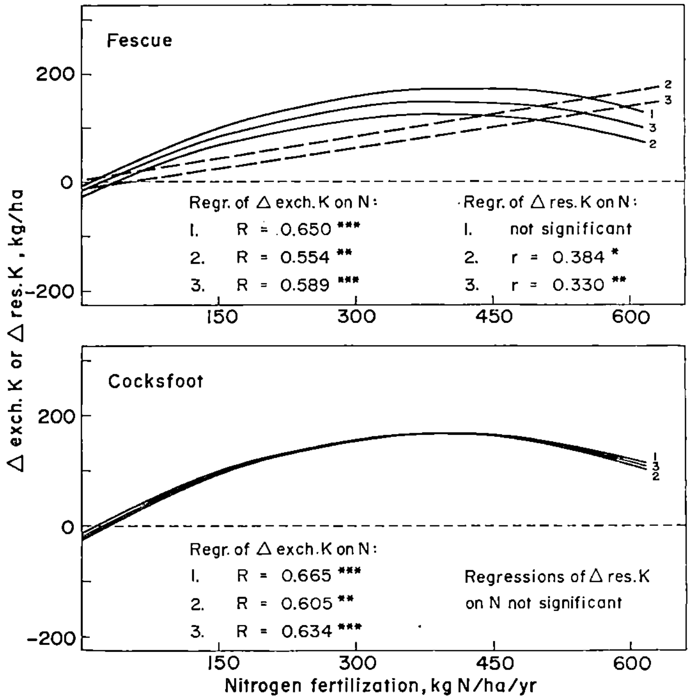

Fig. 2. The three year change in soil exchangeable (solid lines) and reserve (broken lines) potassium on fescue and cocksfoot plots as a function of N fertilization on fine (1), coarse (2) and all (3) mineral soils. Significance levels 99.9***, 99** and 95* per cent.

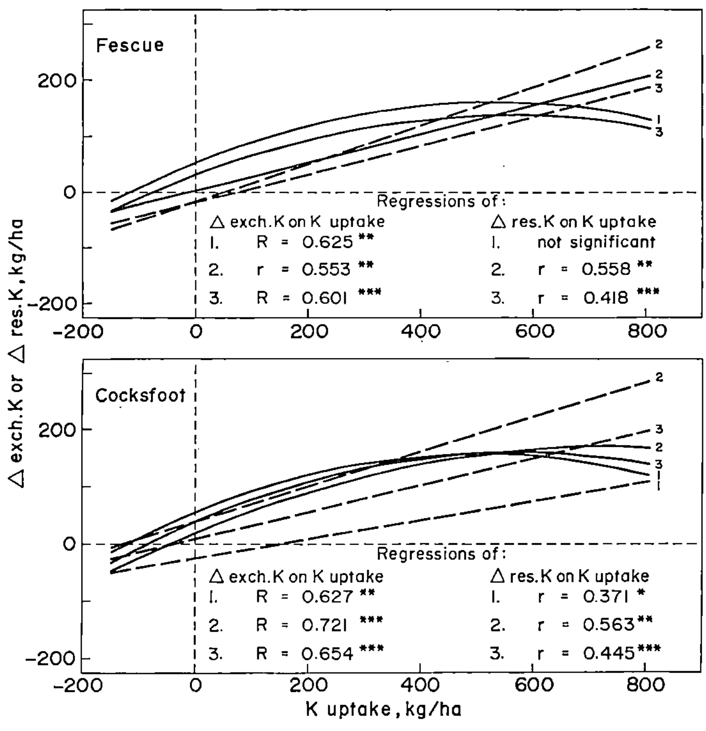

Fig. 3. The three year change in soil exchangeable (solid lines) and reserve (broken lines) potassium on fescue and cocksfoot plots as a function of potassium uptake. 1 = fine, 2 = coarse and 3 = all mineral soils. Significance levels 99.9***, 99** and 95* per cent.

Table 2. Analytical data used to calculate regressions given in Table 3 where symbols A — D are also used in regression equations. All dimensions kg/ha.

Site	Appl. N kg/ha/yr	FINE SOILS: FESCUE 0	150	300	450	600	FINE SOILS: COCKSFOOT 0	150	300	450	600
1. KVL	A = K uptake	−208	114	244	310	296	−210	126	292	274	300
	B = △ exch K	20	200	280	260	260	20	190	260	280	280
	C = △ res K	−362	−230	−260	−150	−178	−138	−178	−266	−292	−196
	D = △ K	−342	−30	20	110	82	−118	12	−6	−12	84
2. LOU	A = K uptake	−124	246	554	686	724	−78	374	662	798	736
	B = △ exch K	0	80	220	200	140	20	140	120	140	60
	C = △ res K	48	108	50	372	476	244	248	316	214	268
	D = △ K	48	198	270	572	616	264	388	436	354	328
3. KAR	A = K uptake	−84	420	710	660	688	−36	718	1048	978	1018
	B = △ exch K	−80	40	80	40	40	−80	20	80	40	50
	C = △ res K	98	28	90	114	64	8	−10	2	66	20
	D = △ K	18	68	170	154	104	−72	10	82	106	70
4. SAT	A = K uptake	−160	130	390	430	470	−240	112	274	356	368
	B = △ exch K	50	120	130	150	160	10	160	160	180	150
	C = △ res K	−16	36	26	−44	20	−152	−74	24	32	−12
	D = △ K	34	156	156	106	180	−142	86	184	212	138
5. EPO	A = K uptake	44	368	624	694	696	72	410	554	688	654
	B = △ exch	40	160	240	220	240	−60	100	220	180	220
	C = △ res K	−94	34	−124	44	30	68	226	150	226	86
	D = △ K	−54	194	116	264	270	8	326	370	406	306
6. KSU	A = K uptake	−194	158	282	222	248	−162	204	318	286	122
	B = △ exch K	−116	26	70	46	36	−100	76	66	46	20
	C = △ res K	100	194	178	282	230	−26	−24	106	92	80
	D = △ K	−16	220	248	328	266	−126	52	172	138	100

tion in this ratio within each of the two texture groups. The wide ratio of 1 : 10 for NH_4 acetate- : HCl-extractable K makes difficulties in estimating small changes in the potassium status of the soil. Thus a 30 % fall in exchangeable K corresponds to only a 3 % fall in acid-extractable (ie. exchangeable + reserve) K. This is very close to the precision limit for K determinations by the AA technique.

The two peats did not conform to the 1 : 10 : 100 pattern. The Sphagnum peat (LET) which contained some mineral matter gave 3 : 25 : 100 and the Carex peat (PRP) 25: 31 : 100. Analytical data were complete only for LET. Thus, while the results of analyses made on it are given in tables, they were not included in any of the statistical studies.

T h e e f f e c t o f n i t r o g e n fertilization upon net potassium u p t a k e of fescue and cocksfoot during the three year period as well as changes in exchangeable and reserve potassium at various nitrogen levels is summarized in Table 2. Various symbols and abbreviations used in this study are also given here. The best-fitting linear or curvilinear regression expressing K uptake (kg/ha) as a function of N fertilization (kg/ha/year) is determined for separate and combined soil

A = net uptake = K uptake by plants 1966—69 minus 300 kg K/ha given in fertilizers (abbrev. K uptake)
B = fall in soil exchangeable K from 1966 to 1969, (abbrev. △ exch K)
C = fall in reserve K from 1966 to 1969, (abbrev. △ res K)
D = B + C, (abbrev. △ K); equals change in HCl-extractable K.

Site	Appl. N kg/ha/yr	COARSE SOILS: FESCUE 0	150	300	450	600	COARSE SOILS: COCKSFOOT (TIMOTHY at PPO) 0	150	300	450	600
7. HÄM	A = K uptake	−146	230	522	636	666	−96	428	818	870	932
	B = △ exch K	−40	80	80	90	40	−20	130	160	110	100
	C = △ res K	−38	8	374	490	348	280	558	316	588	436
	D = △ K	−78	88	454	580	388	260	688	476	698	536
8. TOH	A = K uptake	−104	416	504	538	544	−172	398	546	604	548
	B = △ exch K	−20	160	210	180	200	10	190	240	220	240
	C = △ res K	106	188	64	216	110	64	10	308	260	172
	D = △ K	86	348	274	396	310	74	200	548	480	412
9. KPO	A = K uptake	−224	104	334	368	380	−212	184	364	430	404
	B = △ exch K	−140	80	190	180	200	−170	140	210	190	190
	C = △ res K	20	106	72	34	36	32	102	82	112	76
	D = △ K	−120	186	262	214	236	−138	242	292	302	266
10. LAI	A = K uptake	−76	360	448	404	534	−50	602	796	818	936
	B = △ exch K	−70	140	130	100	60	−50	180	140	280	140
	C = △ res K	−192	−200	18	46	−46	−166	34	336	86	70
	D = △ K	−262	−60	148	146	14	−216	214	476	366	210
11. ESA	A = K uptake	−42	224	268	330	280	−36	266	302	322	318
	B = △ exch K	80	100	110	120	120	90	120	140	140	140
	C = △ res K	54	36	126	132	50	110	136	196	166	140
	D = △ K	134	136	236	252	170	200	256	336	306	280
12. PPO	A = K uptake	−174	232	390	398	418	−214	204	316	344	302
	B = △ exch K	−50	−10	−60	−60	−80	−20	−10	−20	−20	−60
	C = △ res K	−198	210	108	90	138	−310	66	112	86	184
	D = △ K	−248	200	48	30	58	−330	56	92	66	124
PEAT SOIL											
13. LET	A = K uptake	−190	310	552	630	566	206	308	560	656	668
	B = △ exch K	−100	140	150	190	200	−100	120	180	160	160
	C = △ res K	104	388	454	246	388	184	304	444	456	384
	D = △ K	4	528	604	436	588	84	424	624	616	544

groups, for fescue and for cocksfoot. The regressions with R-values and their significance levels are given in Table 3. In all cases the relationships are highly significant and the curvilinear fit is significantly better than the linear. In Fig. 1 the best-fitting curvilinear regressions are shown.

For both plants, K uptake is maximal at a little over 450 kg N/ha/year. At this level fescue takes up about 4 times, and cocksfoot 4 ½ times as much potassium as at the control level. It should be remembered, however, that the data represent material harvested over a period of three years. How effectively the plants take up potassium in individual harvests and seasons comprising this period is not dealt with here. Suffice it to mention that the form of these curves is greatly influenced by a fairly readily available supply of potassium during the first year, especially in the case of cocksfoot. High nitrogen dressings stimulate the plant to exhaust these K reserves rapidly. After such heavy withdrawl of K, further high N dressings depress rather than stimulate subsequent K uptake.

T h e c h a n g e o f e x c h a n g e a b l e s o i l p o t a s s i u m, (△ exch K), over the three year cropping period is determined as

Table 3. Regressions of K uptake (A), △ exch K (B) and △ res K (C) on yearly N fertilization (N), and regressions of △ exch K (B), △ res K (C) and △ K (D) on K uptake (A).
All dimensions kg/ha. For symbols see also Table 2.

	FESCUE			COCKSFOOT		
	Regression	corr. coeff.	shown graphically in Fig.	Regression	corr. coeff.	shown graphically in Fig.
Fine soils	$A = -112.6 + 2.70\ N - 0.00276\ N^2$	0.835***	1	$A = -\ 90.4 + 3.10\ N - 0.00348\ N^2$	0.717***	1
Coarse soils	$A = -104.6 + 2.52\ N - 0.00266\ N^2$	0.903***	1	$A = -102.4 + 3.12\ N - 0.00340\ N^2$	0.797***	1
F. + C. soils	$A = -108.6 + 2.62\ N - 0.00272\ N^2$	0.861***	1	$A = -\ 96.4 + 3.12\ N - 0.00344\ N^2$	0.755***	1
Fine soils	$B = -\ 9.8 + 0.882\ N - 0.00104\ N^2$	0.650***	2	$B = -21.0 + 0.928\ N - 0.00114\ N^2$	0.665***	2
Coarse soils	$B = -28.2 + 0.776\ N - 0.00098\ N^2$	0.554***	2	$B = -15.2 + 0.928\ N - 0.00116\ N^2$	0.605***	2
F. + C. soils	$B = -19.0 + 0.830\ N - 0.00102\ N^2$	0.589***	2	$B = -18.2 + 0.982\ N - 0.00116\ N^2$	0.634***	2
Fine soils	not significant			not significant		
Coarse soils	$C = 2.6 + 0.270\ N$	0.384*	2	» »		
F. + C. soils	$C = -15.4 + 0.256\ N$	0.330**	2	» »		
Fine soils	$B = 52.8 + 0.408\ A - 0.000385\ A^2$	0.625**	3	$B = 56.6 + 0.412\ A - 0.000405\ A^2$	0.627**	3
Coarse soils	$B = 6.6 + 0.220\ A$	0.553**	3	$B = 20.1 + 0.413\ A - 0.000280\ A^2$	0.721***	3
F. + C. soils	$B = 32.3 + 0.380\ A - 0.000335\ A^2$	0.601***	3	$B = 39.4 + 0.422\ A - 0.000365\ A^2$	0.654***	3
Fine soils	not significant			$C = -24.7 + 0.167\ A$	0.371*	3
Coarse soils	$C = -16.2 + 0.342\ A$	0.558**	3	$C = 39.9 + 0.305\ A$	0.563**	3
F. + C. soils	$C = -17.4 + 0.256\ A$	0.418***	3	$C = 8.8 + 0.234\ A$	0.445***	3
Fine soils	$D = 230.6 + 0.394\ A$	0.651***		$D = 120.8 + 0.852\ A - 0.000275\ A^2$	0.689***	
Coarse soils	$D = 111.9 + 0.561\ A$	0.721***		$D = 278.2 + 0.514\ A$	0.728***	
F. + C. soils	$D = 183.9 + 0.461\ A$	0.677***		$D = 332.7 + 0.905\ A - 0.000275\ A^2$	0.680***	

the difference between exchangeable K on 1966 and on respective 1969 samples. The influence of potassium fertilization amounting to 300 kg K/ha over the three year period is included in the difference. Its effect on this difference can be considered to be partly decreasing (increases the exch. K in 1969) and partly increasing (increases K uptake through increased yields).

The changes in exchangeable and reserve potassium (△ exch K and △ res K) and their sum (△ K) for the various experimental sites at different N fertilization levels appear in Table 2 and corresponding regressions on N for different soil groups and plants in Table 3 and Fig. 2. Similar regressions on K uptake are given in Table 3 and Fig. 3.

All of the correlations relating △ exch K to N are significant and in all cases the curvilinear correlations are significantly better than the linear. Attempts to correlate △ res K with N revealed only two significant correlations. This may be due to errors in sampling and extraction as well as the lack of sensitivity of the analytical technique used.

The △ exch K curves follow a similar trend to the uptake curves discussed in the previous section. All are curvilinear, with a maximum value of △ exch K near 450 kg N/ha. They are much flatter, however, than the uptake curves. This is partly due to the fact that also reserve potassium contributes to uptake. The 3 year change in HCl-extractable K (△ K) seems to be the best measure in this study for the change in soil K status during the experiment. Nevertheless, correlations of △ K with N are not as good as the K uptake-N -correlations.

Long-term effects of nitrogen fertilization on soil potassium depend on the initial potassium content of the soil. In some soils, the initial amounts of HCl-extractable K are so low (TOH, KPO and ESA, Table 1), that the loss in HCl-extractable K (D in Table 2) from these soils due to uptake at high N levels in only three years is substantial

(20—40 % of initial values). These soils cannot support high rates of potassium uptake for much longer. In the case of the Sphagnum peat (LET), the percentage depletion is likewise near 30 %. In peat soils roots tend to be confined to the top 20 cm, so that an even more rapid fall-off in K uptake is expected on this soil.

In attempting correlations of △ exch K with K uptake, the uptake is taken as the independent variable, since it gives better correlations than when the axes are reversed. The regressions are expressed graphically in Fig. 3, and the equations given in Table 3.

All of the △ exch K/K uptake regressions are significant or highly significant. In all but one case curvilinear regressions are given. Linear regressions between △ res K and K uptake are significant or highly significant, with two exceptions.

The change in HCl-extractable K (△ K) is better correlated with uptake than is either of its components alone (△ exch K or △ res K) (Table 3). All such correlations are highly significant. It appears that differences in HCl-extractable K describe better the long-term changes in soil potassium than differences in exchangeable K.

This may be due partly to replacement (from reserve sources) of exchangeable K taken up by plants. This diminishes the loss in exchangeable K and worsens the correlations of △ exch K on K uptake. The same may apply also to reserve K but apparently to a far lesser extent. Another possible factoı acting in the same direction is the uptake of K from depths below 20 cm not taken into account.

Exchangeable K is evidently a much better indicator of the immediately available sources of K for plants than reserve K or HCl-extractable K, but due to its replacement from other K forms exchangeable K is a rather poor measure of long-term changes.

For the whole material (both plants, all

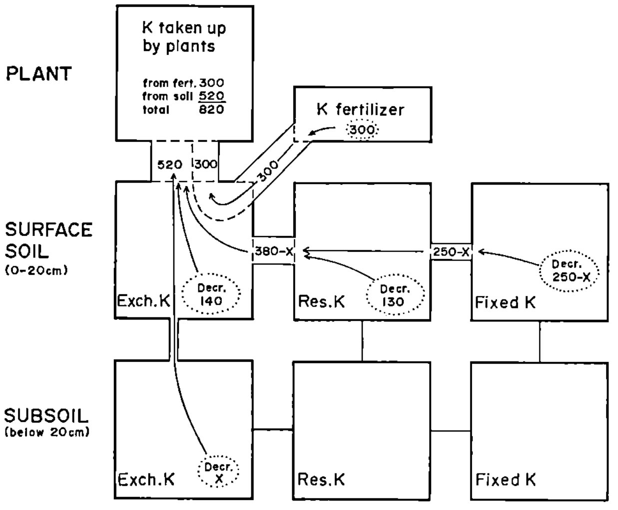

Fig. 4. Simplified scheme of the three-year uptake of K (kg/ha) by plants (aver. all soils, both plants at the 450 kg/ha/yr nitrogen fertilization level) from K fertilizer and soil K sources.

soils) maximum mean three year potassium uptake occurred at the 450 kg N fertilization level and was 820 kg K/ha. Since 300 kg K/ha was replaced as fertilizer over this period, the soil potassium reserves have diminished by 520 kg/ha. This net decrease is nearly twice as high as the corresponding mean loss in HCl-extractable K, which was 270 kg K/ha, or nearly four times as high as the respective fall in exchangeable K (140 kg/ha). Thus, the net uptake exceeds $\triangle$ K by 250 kg/ha, and $\triangle$ exch K by 380 kg/ha. The 250 kg/ha must come either from soil depths below 20 cm or from soil K reserves not extractable by HCl.*) The present results do not show which of these mechanisms plays the main role, but if potassium uptake by the grasses follows the quantitative distribution of their root systems (eg. SALONEN 1949) about 5—10 % of gross potassium uptake may have come from the subsoil (below a 20 cm depth) or roughly 40—80 kg/ha. Correspondigly, 170—210 kg/ha of fixed K would become available to plants. The three year uptake of the grasses (at the 450 kg N/ha level) from various K sources is shown in simplified form in Fig. 4. Other possible mechanisms accounting for small parts of this discrepancy are downward and upward movements of K in the soil profile.

*) Soil sampling was done to a 20 cm depth. Therefore the analytical results describe the changes only in this layer on a kg/ha basis.

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SELOSTUS

Nurmille annettujen suurten typpilannoitemäärien vaikutus maan kaliumiin

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Typpilannoituksen (0—600 kg N/ha/v.) vaikutusta nurmikasvien (koiranruoho ja nurminata) kaliumin ottoon ja muutoksiin maan kaliumtilanteessa kolmivuotisena koejaksona tutkittiin 14:llä paikkakunnalla sijaitsevien kokeiden perusteella.

Molempien kasvien kaliumin otto saavutti maksiminsa vähän yli 450 kg/ha typpilannoitustasolla (Kuva 1), jolloin nurminadan kaliumin otto oli n. 4- ja koiranheinän n. 4 ½-kertainen ilman typpeä jääneeseen koejäseneen verrattuna.

Koko aineistossa (molemmat kasvit ja kaikki maalajit) kolmivuotisen koejakson kaliumin oton maksimi (450 kg N/ha/v.-tasolla) oli 820 kg K/ha. Kun kaliumia on lannoitteina vastaavana aikana annettu yhteensä 300 kg/ha ovat maan kaliumvarat vähentyneet 520 kg/ha. Tämä määrä on lähes kaksinkertainen 1-normaaliseen suolahappoon uuttuvan maan kaliumin (ns. reservi K + vaihtuva K) vähenemiseen (270 kg/ha) ja lähes nelinkertainen maan vaihtuvan kaliumin vähenemiseen (140 kg/ha) verrattuna. Edellä olevista luvuista laskettuna tulee ns. reservikaliumin vähennykseksi (270—140) 130 kg/ha. Nämä kaliumlähteiden (vaiht. K + res. K) nettovähennykset pystyvät selittämään vain runsaan puolet maan kaliumin kokonaisvähennyksestä ja kasvien tämän määrän yli ottaman (250 kg/ha) kaliumin täytyy olla peräisin maan muista kaliumlähteistä. Tällöin tulevat kysymykseen lähinnä sellaiseen muotoon pidättynyt kalium, joka ei uutu suolahappoon, mutta on koejakson aikana korvannut reservikaliumin ja vaihtuvan kaliumin menetyksiä ja toisaalta kasvien suoraan pohjamaasta ottama kalium (lähinnä vaihtuva K)*). Tulokset eivät osoita näiden kahden kaliumlähteen keskinäistä kvantitatiivista suhdetta, mutta mikäli kasvien kaliumin otto seuraa juuriston kvantitatiivista jakautumaa (esim. SALONEN 1949) lienee pohjamaasta (20 cm:ä syvemmältä) tapahtunut kaliumin otto 5—10 %:n luokkaa kaliumin kokonaisotosta eli suunnilleen 40—80 kg/ha.

Vastaavasti olisi voimakkaasti pidättynyttä (fixed) kaliumia tullut kasveille käyttökelpoisempiin muotoihin 170—200 kg/ha. Kuvassa 4 on kasvien kolmivuotinen kaliumin otto (450 kg/ha typpilannoitustasolla) eri K-lähteistä esitetty yksinkertaistettuna kaaviona.

Jatkuvan voimakkaan typpilannoituksen vaikutus maan kaliumtilanteeseen riippuu suuresti maan alkuperäisistä kaliumvaroista. Suoritetut kolmivuotiset kokeet jo osoittavatkin, että eräiden maiden kaliumvarat eivät kauankaan pysty tyydyttämään liian yksipuolisen ja voimakkaan typpilannoituksen kiihdyttämää kasvien kaliumin oton tarvetta.

*) Maanäytteet on otettu pintamaasta (0—20 cm) ja maa-analyysien tulokset kuvastavat vastaavasti muutoksia siinä kerroksessa hehtaaria kohti laskettuna.

ANNALES AGRICULTURAE FENNIAE, VOL. 12: 185—189 (1973)

Seria AGROGEOLOGIA ET -CHIMICA N. 65 — Sarja MAA JA LANNOITUS n:o 65

THE EFFECTS OF SIMULTANEOUS ADDITION OF AMMONIUM AND POTASSIUM ON THEIR FIXATION IN SOME FINNISH SOILS

Jouko Sippola, Raimo Erviö and Roelof Eleveld

Sippola, J., Erviö, R. & Eleveld, R. 1973. **The effects of simultaneous addition of ammonium and potassium on their fixation in some Finnish soils.** Ann. Agric. Fenn. 12: 185—189.

The fixation of ammonium and potassium when added simultaneously to six clay soils was studied. In one experiment the ions not fixed were extracted after one hour's reaction and in the other, after three months' incubation.

15 to 82 % of 1 me NH_4/100 g soil was fixed when added with 5 me K; the percentage of fixation decreased when the quantity of added ammonium was increased. 28 to 48 % of 1 me K/100 g soil was fixed when added with 4 me NH_4. The quantity of fixed ammonium was 1.6 to 2 times greater than that of potassium in four soils having a pH 5.3—5.8 measured in 0.01 *M* $CaCl_2$ suspension. Two soils with pH 4.7 and 4.8 fixed greater or equal quantities potassium than ammonium. These two soils also had a relatively low vermiculite content. More potassium was fixed than ammonium when the respective ions were added alone.

In the incubation experiment, the three soils studied all seemed to fix more ammonium than potassium.

Introduction

Using Swedish soils, Jansson and Ericsson (1961) have demonstrated in pot experiments that fixed ammonium may not be available to plants when potassium is applied at the same time. In field experiments such effect was not clearly observed. Nömmik (1957), studying a Swedish soil rich in vermiculite, found that more ammonium was fixed than potassium when the ions were added simultaneously.

Vermiculite, the mineral mainly responsible for fixation of ammonium and potassium, is a common constituent in Finnish soils (Soveri 1956). The amount of vermiculite is highest in the finest fractions of Finnish soils (Sippola 1972) and the degree of fixation of ammonium and potassium has been found to correlate with the content of clay (Kaila 1962, 1965).

The purpose of the present study was to investigate the fixation of ammonium and potassium in Finnish soils when applied simultaneously.

Materials and methods

Soils used in this study were collected from the clay area in Southern Finland. Samples were taken from depths between 20 and 40 cm. Soil No. 4 is a virgin soil, all others are

Table 1. Soil samples.

No.	Soil type	Org. C %	pH H_2O	pH $CaCl_2$	Particle size distribution <2	2–20	20–200	>200 µm	CEC me/100 g	Base saturation %	Exch. K me/100 g	Vermiculite %
1	Heavy clay	1.0	5.3	4.7	84	11	5	—	24.9	71	.70	4.2
2	Silty clay	.7	5.2	4.8	59	32	9	—	19.7	74	.52	2.8
3	Silty clay	.9	6.3	5.7	59	27	8	6	22.6	87	.61	5.7
4	Silty clay	.6	6.6	5.8	56	28	11	5	23.2	89	.29	6.7
5	Silty clay	1.0	6.3	5.7	53	32	14	1	23.8	86	.53	5.3
6	Sandy clay	.6	5.7	5.3	40	15	43	2	18.0	82	.27	4.8

from cultivated fields. Some of the properties of these soils are shown in Table 1. Organic carbon was determined by the dichromate method using external heat. The pH values were measured in water and in 0.01 *M* $CaCl_2$ suspensions (1: 2.5), and particle size distribution was determined by the pipette method. Cation exchange capacity is the sum of Ca, Mg, K, Na and H exchangeable into 1 *N* neutral NH_4-acetate. The percentage of vermiculite has been determined according to the method proposed by ALEXIADES and JACKSON (1965).

In the first experiment, samples of 5 g soil in a series of 100 ml centrifuge tubes were first treated with a 25 ml solution containing increasing amounts of NH_4Cl and a constant amount of KCl. The concentrations appear in Fig. 1. Another set of 5 g soil samples in centrifuge tubes was treated with 25 ml solutions containing increasing amounts of NH_4Cl with decreasing amounts of KCl. The concentrations appear in Fig. 3. Replicates were made of both treatments. After adding the solutions, the tubes were shaken for one hour, then 25 ml of 1 *N* $CaCl_2$ solution was added and they were again shaken for one hour. Clear suspensions were obtained by centrifuging.

In the second experiment, the fixation of ammonium and potassium over a prolonged period was studied in an incubation test. One litre of soil was measured and ammonium and potassium chlorides were added as mixed solutions. The concentrations used appear in Fig. 4. Treatments were prepared in triplicate. Pots were moistened to 60 % of field capacity and incubated for three months at room temperature. At the end of the incubation period exchangeable ammonium and potassium were extracted using 1 *N* Ba-acetate. Soils were not dried before extraction. In all experiments ammonium was determined by steam distillation and potassium, using atomic absorption spectrophotometry.

Results and discussion

The results given in Fig. 1 show that when applied simultaneously the fixation of the constant addition of potassium (5 me/100 g soil) decreases with increasing rates of ammonium. Soils 3, 4, 5 and 6 fixed 68 to 82 % of the 1 me ammonium added. The percentage fixation decreased when the ammonium concentration was increased. When 4 me was added, 39 to 49 % was fixed. At the same time the amount of potassium fixed decreased from 43 to 57 % when no ammonium was added, to about 25 % when 4 me ammonium was added. The sum of fixed ammonium and potassium increased slightly when the concentration of added solution increased. It is evident that the same process is involved in the fixation of both ions as was found with Swedish and Danish soils (NÖMMIK 1957, DISSING NIELSEN 1971). The sum of ammonium and potassium fixed (4 me NH_4+5 me K added to 100 g soil) correlated with the percentage of vermiculite estimated by chemical methods (r = .88*) but not with clay percentage or exchangeable potassium. The precedence of ammonium over potassium in

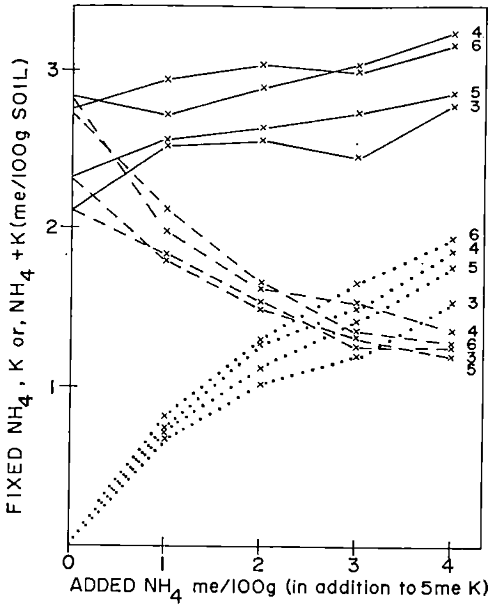

Fig. 1. Fixation of NH_4 and K, simultaneously added in soils 3, 4, 5 and 6. Symbols: · · · · fixed NH_4, — — — — fixed K and ——— fixed NH_4 + K.

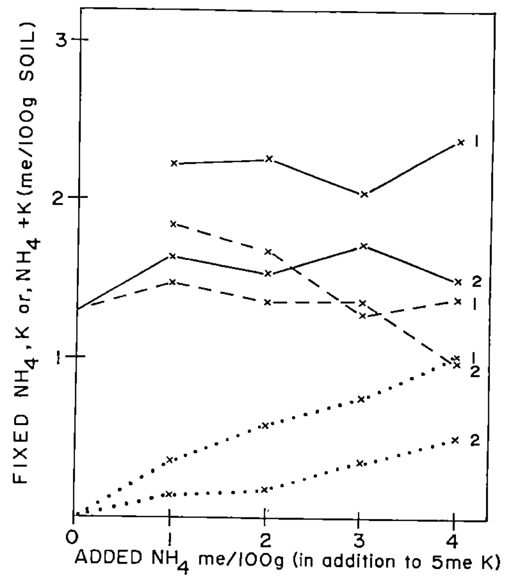

Fig. 2. Fixation of NH_4 and K, simultaneously added in soils 1 and 2. Symbols: · · · · fixed NH_4, — — — — fixed K and ——— fixed NH_4 + K.

fixation found in the soils shown in Fig. 1 is in accordance with the Swedish and Danish results. The phenomenon is explained by a lower hydration energy and a larger size of ammonium than potassium ion. Lower hydration energy allows the ammonium to collapse the layers of vermiculite more easily than the potassium (KITTRIC 1966). The movement and exchange of ammonium is blocked when potassium is fixed at the edges of crystals. Soils 1 and 2 (Fig. 2), however, showed a preference for potassium fixation. Only 13 and 25 % of the 4 me ammonium added was fixed compared to 20 and 28 % fixations of 5 me of potassium. These two soils differ from the other soils studied in that they have a lower vermiculite content. Also pH and degree of base saturation are lower than in other soils, indicating a higher degree of hydrogen and aluminium saturation. It is possible that aluminium and its hydrolysed forms, found in interlayers of vermiculite, restrict collapsing and that other factors therefore determine the fixation process.

Fig. 3 shows the results of treatments where increasing quantities of ammonium were added with decreasing quantities of potassium while the total concentration was held constant, 5 me/100 g soil. The preference for ammonium fixation over potassium is also very clear here, apart from soil 2. It may be calculated that when 2.5 me of both ions were added the ratio of fixed NH_4 to fixed K varied from 1.6 to 2.0 with the soils which preferred ammonium. DISSING NIELSEN (1971) found ratios ranging from 1.3 to 2.0 in Danish soils. NÖMMIK (1957), studying a Swedish soil which had a high capacity to fix ammonium, found a NH_4/K fixation ratio of 3.4.

When only 5 me ammonium or only 5 me potassium were added to the soil, more potassium was fixed than ammonium (Fig. 3). Similar results have been reported from Danish soils (DISSING NIELSEN 1971).

In the second experiment, the effect of time on ammonium and potassium fixation was studied in an incubation test. In Fig. 4 it is seen that fixation generally proceeded in the

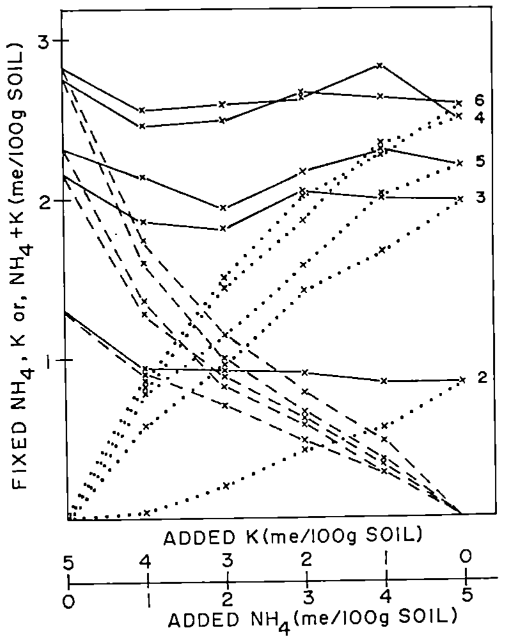

Fig. 3. Fixation of NH_4 and K from solutions containing increasing and decreasing concentrations of the respective ions in soils 2, 3, 4, 5 and 6. Symbols: · · · · fixed NH_4, — — — — fixed K and ——— fixed NH_4 + K.

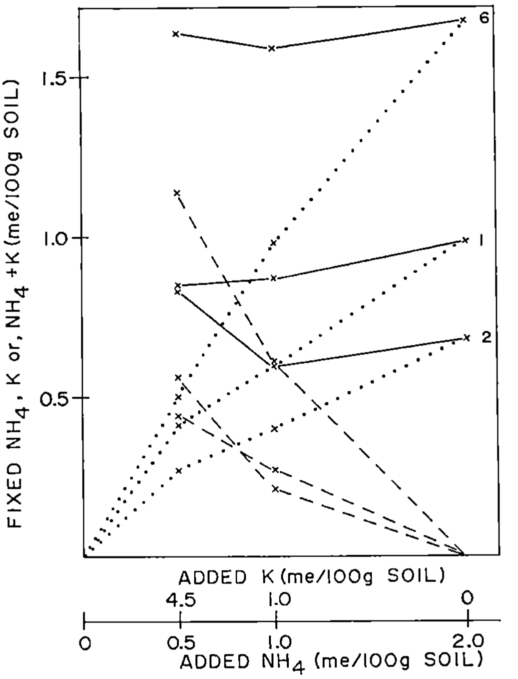

Fig. 4. Fixation of NH_4 and K in the incubation test in soils 1, 2 and 6. Symbols: · · · · fixed NH_4, — — — — fixed K and ——— fixed NH_4 + K.

same way as in other experiments and ammonium seemed to be preferred to potassium. With soil 6 the ratio of fixed NH_4 to fixed K was 1.6 (1 me of each added) compared to 2.0 in the other experiment (Fig. 3, 2.5 me of each added). With soils 1 and 2 this ratio was 1.9 and 2.2 showing a considerable increase in ammonium fixation compared to the first experiment (Fig. 2). This contrasts with the findings of Nömmik (1957), who found that small quantities of fixed ammonium are released to nitrifying organisms during incubation. Jansson (1958) also found that at least part of the fixed ammonium is converted to nitrates during one month's incubation. The reason for the apparent increase in ammonium fixation during incubation may be that the added non-fixed ammonium was partly nitrified, and thus the calculations lead to values which are too high. Determination of nitrates would have clarified this question.

The results suggest, that Finnish clay subsoils may fix ammonium and potassium in fairly large quantities. Previous studies also indicate similar results (Kaila 1962, 1965). Regarding these plant nutrients, fixation may impair their availability shortly after application, but fixed nutrients may be released to plants when the concentration in soil solution diminishes. The fixation of ions diminishes the danger of leaching, and therefore, fixation may not be considered only as an unfavourable phenomenon.

In practice, due to less thorough mixing of fertilizer and soil, fixation may be lower than in laboratory experiments. Therefore also granulation and the banding placement of fertilizers restrict fixation. Surface soils, due to a higher content of organic matter and lower clay content, may also fix ammonium and potassium to a lesser extent (Kaila 1962, 1965) than the subsoils under this study.

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SELOSTUS

Ammoniumin ja kaliumin samanaikaisen lisäyksen vaikutus niiden pidättymiseen savimaissa

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Ruotsissa on astiakokeissa todettu, että ammoniumtyppi samanaikaisesti kalilannoituksen kanssa käytettynä vaikuttaa savimaissa huonommin kuin nitraattityppi. Vermikuliitti, savimineraali, joka pidättää ammoniumia ja kaliumia vaihtumattomaksi, on tavallinen suomalaisissa maissa. Vermikuliittia on erityisesti savimaissa, joita on noin kolmannes Suomen pelloista.

Aitosavi-, hietasavi- ja neljä hiesusavimaata oli mukana laboratoriossa tehdyissä kokeissa. Ensimmäisessä kokeessa käsiteltiin maata samanaikaisesti kaliumilla ja nousevilla määrillä ammoniumia (kuvat 1 ja 2). 1 me:n ammoniumin lisäyksestä (lisäys vastaa 280 kg N/ha/20 cm) pidättyi 15—82 % ja suuremmista lisäyksistä suhteellisesti vähemmän. Kaliumia pidättyi samanaikaisesti 29—42 % lisätystä 5 me:stä (lisäys vastaa 780 kg K/ha/20 cm). Toisessa käsittelyssä lisättiin maahan nousevat ammoniummäärät kaliumin lisäyksiä samanaikaisesti pienentäen (kuva 3). Tällöin todettiin, että lisättäessä 2.5 me kumpaakin ionia, ammoniumia pidättyi neljässä koemaassa 1.6—2 kertaa niin paljon kuin kaliumia. Kaksi muuta maata pidättivät enemmän kaliumia kuin ammoniumia.

Muhituskokeessa tutkittiin kolme kuukautta kestäneen muhituksen vaikutusta ammoniumin ja kaliumin pidättymiseen. Kokeen päätyttyä tehdyissä määrityksissä todettiin vaihtuvan ammoniumin määrän olevan suhteellisesti pienemmän kuin edellä selostetuissa kokeissa ja siten pidättyneen ammoniumin olevan suuremman. Mainittu ammoniumin määrän alentuminen saattoi kuitenkin osittain johtua ammoniumin muuttumisesta nitraatiksi, kuten tämäntapaisissa kokeissa yleensä on voitu havaita.

Vaikka kokeissa todettu ammoniumin ja kaliumin pidättyminen vaikuttaa suurelta, niin lannoitteiden rakeistaminen ja niiden sijoittaminen maahan nauhaksi vähentää maan kanssa tapahtuvia reaktioita ja siten myös pidättymistä. Myöskin muokkauskerroksen maa pidättää pienemmän savilajitteen ja suuremman orgaanisen aineksen määrän takia vähemmän kuin jankon maa, mistä kokeessa käytetyt näytteet oli otettu. Koska pidättyvät ionit vapautuvat, kun maanesteen konsentraatio alenee, niin pidättymistä voidaan pitää hyödyllisenä maan ominaisuutena sen vähentäessä ravinteiden huuhtoutumista pois.

ANNALES AGRICULTURAE FENNIAE, VOL. 12: 190—199 (1973).
Seria HORTICULTURA N. 23 — Sarja PUUTARHAVILJELY n:o 23

VARIETY TRIALS WITH THE HIGHBUSH BLUEBERRY IN FINLAND

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The trials undertaken with the highbush blueberry at the Institute of Horticulture are intended to reveal the fitness of the different varieties for cultivation in Finland, and to discover the varieties that could most probably be suited to cultivation by breeding.

The highbush blueberry does in fact produce good fruit in Finland. On the other hand, in most of the varieties the fruit yield is very small, and even in the best varieties it shows marked variation. In Finland, the highbush blueberry is particularly susceptible to frost damage and the blueberry cancer caused by the fungus *Fusicoccum putrefaciens* Shear. Precisely these factors have contributed to the poor results obtained with trial crops in Finland.

When all the trial years are considered, the varieties that overwintered best were 'June', 'Rancocas' and 'Atlantic'. 'Rancocas' had the best resistance to blueberry cancer. 'Jersey' was the most vigorous and 'Atlantic' was clearly the tallest-growing. The most productive varieties were 'Rancocas', 'June', 'Pemberton' and 'Atlantic', and that with the largest berries was 'Bluecrop'. 'June' and Earliblue' were very early varieties; 'Atlantic' was early and 'Rancocas', 'Pemberton' and 'Scammel' were moderately early. When all the seven investigated characters are considered, 'June' and 'Rancocas' are clearly more suitable for cultivation than the other varieties.

Breeding is in progress at the Institute of Horticulture, with a view to developing varieties that are suited to Finnish climatic conditions, attempts being made to cross native *Vaccinium* species with highbush blueberry varieties. So far, only crossing with *V. uliginosum* L. has been successful. The most suitable progeny was obtained from the cross 'Bluecrop' × (*V. uliginosum* × 'Rancocas').

As a result of active breeding performed within the genus *Vaccinium*, the highbush blueberry has become one of the most important berry plants in the United States. At the beginning of this century the blueberry was still only a wild plant in America, but in 1908—1909 breeding was commenced with a view to the cultivation of the blueberry (COVILLE 1910, DARROW 1960). The original material consisted of the bush-like species *V. australe* Small and *V. corymbosum* L. and the dwarf shrub-like species *V. lamarckii* Camp. At first breeding was performed with individuals chosen from natural stands, but later it was mainly based on crosses between various species and varieties (COVILLE 1937, DARROW

1960). In this way considerable progress was made in developing various properties of the highbush blueberry that are valuable from the point of view of cultivation (cf. MOORE 1965). Many European countries also became interested in the highbush blueberry and began to investigate its suitability for cultivation (cf. e.g. LIEBSTER 1961, 1967, PERRIN and DUGGAN 1965, ADAMIČ and OBLAK 1967, DALBRO 1967, EVERETT 1967, EYNARD 1967, KLEIN 1967, KOBEL 1967, KRONENBERG 1967, LAMB 1967, ROACH 1967, ROELOFSEN 1967, CORMACK 1971, GROVEN 1971, GRANBERG 1972).

Plants of ten different highbush blueberry varieties were imported by the Institute of Horticulture at Piikkiö, Finland, as early as in the spring of 1947. The first observations indicated that many of the varieties thrived at least satisfactorily in southwest Finland, and the most suitable appeared to be 'Rancocas', 'Pemberton', 'June' and 'Stanley' (VAARAMA 1950a, 1950b, 1953). The hishbush blueberry proved to be demanding in respect of the substrate, thriving only on fine-sand soils with favourable moisture conditions, a high mull content and low acidity, pH 4.5—5.0 (MEURMAN 1955, 1956, MEURMAN and OSARA 1957). It was also found that the highbush blueberry probably thrives only in the south of Finland, since, for example, at the North Savo Experiment Station at Maaninka, the bushes regularly froze above the limit of the snow. Later, in unfavourable winters severe damage was observed in the bushes of the Institute of Horticulture also. In addition, the highbush blueberry was found to be possibly even more deleteriously affected by the fungus *Fusicoccum putrefaciens* Shear (HÅRDH 1959).

Work on the highbush blueberry varieties has been continued at the Institute of Horticulture and so far over 20 varieties have been included in the trials. The characters of the varieties receiving particular attention in recent years have been winter hardiness, resistance to cancer, vigour of growth and productivity. These investigations were intended to reveal the extent to which the varieties were fitted for cultivation in Finland, and also to discover which varieties could most probably be made suitable for cultivation by breeding.

Material and methods

All the bushes of the material investigated were planted out before 1960, and the results presented here relate to the years 1964—1972, so that the bushes may be considered to have been fully mature. The following 17 varieties were included the trial: 'Atlantic', 'Berkeley', 'Bluecrop', 'Burlington', 'Concord', 'Coville', 'Earliblue', 'HSB 46', 'Herbert', 'Ivanhoe', 'Jersey', 'June', 'Kengrape', 'Pemberton', 'Rancocas', 'Rubel' and 'Scammel'. Except in the case of 'Rancocas', for which a larger number of bushes were included, each variety was represented by a few or only one individual.

The trial area is situated on a southeast-facing slope, whose soil is coarser fine sand. In recent years acid milled peat has been used to improve the soil. In the spring fertilizer was applied as follows: ammonium sulphate (N 20 %) 5.0 kg/a, superphosphate (P_2O_5 20 %) 3.5 kg/a and potassium sulphate (K_2O 50 %) 5.0 kg/a. The pH of the soil was 4.5—5.0. The plants were irrigated when required. Weeds were removed mechanically. Protective spraying was not undertaken. Pruning was restricted to the removal of dead and badly damaged shoots or shoot parts.

Winter hardiness and resistance to blueberry cancer were investigated in the years 1967—1972, in the middle of the summer, when the extent of any damage could be sufficiently clearly determined. At the same time the height of the individual bushes was measured, their vigour was determined in 1970—1972 and dead and damaged shoots and shoot parts were removed. A scale ranging from 0 to 100 was used for these observations.

Table 1. Mean values for four characters of highbush blueberry varieties: winter hardiness, resistance to cancer, individual height (means for 1967—1972) and vigour (means for 1970—1972). Ranges of annual means also shown.

Taulukko 1. Pensasmustikkalajikkeiden talvenkestävyys, syövänkestävyys ja yksilökorkeus (vuosien 1967—1972 keskiarvoina) sekä elinvoimaisuus (vuosien 1970—1972 keskiarvoina). Vuosikeskiarvojen välisen vaihtelun osoittavat pienin ja suurin vuosikeskiarvo.

Variety *Lajike*	No. of bushes *Pensaiden lukumäärä*	*)Winter hardiness *)*Talvenkestävyys* 0—100		**)Resistance to cancer **)*Syövänkestävyys* 0—100		***)Vigour ***)*Elinvoimaisuus* 0—100		Individual height *Yksilökorkeus* cm	
		$\bar{x}$	Range *Vaihtelu*	$\bar{x}$	Range *Vaihtelu*	$\bar{x}$	Range *Vaihtelu*	$\bar{x}$	Range *Vaihtelu*
Atlantic	9	77	57— 97	29	0—57	90	85— 96	136	125—154
Berkeley	1	55	10— 80	29	0—60	82	67— 90	93	80—110
Bluecrop	5	51	23— 78	29	13—52	74	67— 80	124	112—141
Burlington	1	71	43—100	27	0—80	86	67—100	96	80—110
Concord	1	60	10—100	35	0—70	64	33— 80	97	70—120
Coville	2	51	15—100	29	0—55	56	33— 70	62	45— 98
Earliblue	1	55	10—100	20	0—70	67	50— 80	72	50—100
HBS 46	1	61	10— 80	24	0—50	76	67— 80	96	80—105
Herbert	1	51	10— 80	21	0—33	72	67— 80	91	80—105
Ivanhoe	1	38	0— 70	8	0—30	72	67— 80	102	90—115
Jersey	1	70	33—100	24	0—60	93	90—100	112	100—125
June	5	85	73— 96	44	20—72	86	84— 88	104	94—115
Kengrape	2	62	33— 95	28	0—70	83	80— 85	93	83— 98
Pemberton	2	56	10— 90	19	0—50	79	67— 85	105	90—123
Rancocas	52	85	73— 97	50	21—67	85	83— 89	116	108—132
Rubel	2	73	60— 95	41	33—75	86	67—100	126	105—153
Scammel	1	66	43— 90	41	0—70	82	67— 90	127	100—145
Total — Koko aineisto	88	77	63— 94	42	17—63	78	68— 85	113	107—130

*) Winter hardiness — *Talvenkestävyys:* 0 = all aerial shoots dead — *kaikki maanpäälliset versot kuolleet,* 100 = completely healthy — *täysin terve*

**) Resistance to cancer — *Syövänkestävyys:* 0 = all shoots infected — *kaikki versot saastuneet,* 100 = completely healthy — *täysin terve*

***) Vigour — *Elinvoimaisuus:* 0 = dead — *kuollut,* 100 = particularly vigourous — *erittäin elinvoimainen*

For winter hardiness 0 = all aerial shoots dead and 100 = completely healthy; for resistance to blueberry cancer 0 = all shoots infected and 100 = completely healthy, and for vigour 0 = dead and 100 = particularly vigorous. The observations were made by the same person throughout the trial period.

When the productivity of the different varieties is assessed, attention should be paid not only to the amount of the fruit yeild but also to its quality and the size of the berries. The fruit yeild was weighed in the years 1964—1972 and recorded as the amount per bush. The weight of the berries was recorded in the years 1967, 1971 and 1972 for all the varieties that has produced berries by that time. The weight of the berries of 'Coville', 'Herbert' and 'Ivanhoe' was estimated on the basis of the yield for 1965. The time of ripening of the fruit was determined on the basis of the picking dates.

Results

Most of the results relating to the suitability for cultivation of highbush blueberry varieties have been concentrated in two tables. Table 1 shows the average winter hardiness, resistance to cancer and individual height of the various varieties in the years 1967—1972 and their average vigour in the years 1970—1972. Table 2 shows the average fruit yield in the years 1964—1972, the average berry weight in the years 1967, 1971 and 1972, and the time of ripening of the fruit.

Table 2. Fruit yield of highbush blueberry varieties (means for 1964—1972), weight of berries (means for 1967, 1971 and 1972) and earliness determined on basis of time of ripening of the fruit. Ranges of annual means also shown.

Taulukko 2. Pensasmustikkalajikkeiden sadon määrä (vuosien 1964—1972 keskiarvoina) ja marjapaino (vuosien 1967, 1971 ja 1972 keskiarvoina) sekä marjojen kypsymisajan perusteella määritetty aikaisuus. Vuosikeskiarvojen välisen vaihtelun osoittavat pienin ja suurin vuosikeskiarvo.

Variety *Lajike*	No. of bushes *Pensaiden lukumäärä*	Fruit yield *Sadon määrä* g/bush *g/pensas*		Wt of berries *Marjapaino* g		*)Earliness *)*Aikaisuus*
		$\bar{x}$	Range *Vaihtelu*	$\bar{x}$	Range *Vaihtelu*	
Atlantic	9	149	0— 586	1.2	1.0—1.3	2
Berkeley	1	44	0— 180	2.4	2.3—2.4	5
Bluecrop	5	94	0— 330	3.0	2.8—3.1	4
Burlington	1	20	0— 120	1.4	1.3—1.4	5
Concord	1	94	0— 155	1.4	1.2—1.6	4
Coville	2	1	0— 10	1.0	1.0—1.0	5
Earliblue	1	10	0— 40	2.0	1.7—2.3	1
HBS 46	1	43	0— 163	2.1	1.7—2.4	4
Herbert	1	1	0— 10	1.0	1.0—1.0	5
Ivanhoe	1	3	0— 20	1.0	1.0—1.0	4
Jersey	1	74	0— 475	1.0	1.0—1.0	5
June	5	438	0—1171	1.2	1.0—1.3	1
Kengrape	2	23	0— 78	1.2	1.1—1.3	4
Pemberton	2	265	0—1160	1.6	1.0—2.1	3
Rancocas	52	464	0—1433	1.2	1.0—1.3	3
Rubel	2	130	0— 340	1.3	1.2—1.4	4
Scammel	1	128	0— 500	2.5	2.5—2.5	3
Total — Koko aineisto	88	331	0— 867	1.6	1.4—1.7	

*) Earliness — *Aikaisuus:* 1 = very early — *hyvin aikainen*
2 = early — *aikainen*
3 = moderately early — *keskiaikainen*
4 = late — *myöhäinen*
5 = very late — *hyvin myöhäinen*

If all the trial years are taken into account, the most reliable winter hardiness was shown by the varieties 'June', 'Rancocas' and 'Atlantic'. Even these varieties suffered considerably in winter 1967—1968, when the varieties 'Berkeley', 'Concord', 'HBS 46', 'Herbert', 'Ivanhoe' and even 'Pemberton' froze almost right down to the ground. In that year the average value for winter hardiness for the whole material was only 63, whereas the corresponding value for the most favourable winter, that of 1971—1972, was 94. The later winters were comparatively favourable and after 1968 most of the varieties survived each winter better than the last.

'Rancocas' showed the best resistance to blueberry cancer, though even its average value was only 50. Only four varieties had healthy bushes in all the trial years, 'Bluecrop', 'June', 'Rancocas' and 'Rubel', and not one of the varieties was completely healthy in any of the years. Cancer was most prevalent in summer 1969 and clearly least prevalent in the growing season of 1972, which had the most favourable thermal and hygric conditions in the trial period.

The varieties differed rather little from each other in respect of vigour. This was no doubt partly attributable to the fact that the observations were restricted to the last three years, when, for example, frost damage was slight. The most vigorous variety appears to be 'Jersey'.

The bushes of the variety 'Atlantic' were clearly the tallest. The lowest-growing were the bushes of 'Coville' and 'Earliblue'. By

1970, the average height of the individuals of the whole trial material was slightly under 110 cm and during the two years preceding summer 1972 it rose to 130 cm.

The fruit harvest varied very widely from year to year. In 1969 there was no yield to speak of, whereas a record yield was obtained in 1970, when the whole material gave 57.8 kg/a, and the best variety, 'Rancocas', produced 95.5 kg/a. The fruit yield also varied very greatly between the varieties. The most productive were 'Rancocas', 'June', 'Pemberton' and 'Atlantic'. The varieties 'Coville' and 'Herbert' gave only a few berries in 1965. 'Atlantic', 'June', 'Rancocas' and 'Rubel' gave regular yields in all the years except 1969.

The heaviest berries were obtained from 'Bluecrop', 'Scammel' and 'Berkeley'. In contrast, the more productive varieties 'Atlantic', 'June' and 'Rancocas' had rather small berries. The weight of the berries varied surprisingly much from year to year.

The fruit of the highbush blueberry normally ripens between 15 August and 15 September. The earliest picking date was in summer 1972, when the fruit of 'June', always the earliest variety, was harvested for the first time on 4 August. The picking dates of the various years were used to determine the time of the ripening of the fruit and to arrange the varieties in various groups in descending order of earliness. Very early varieties: 'June' and 'Earliblue'; early varieties: 'Atlantic'; moderately early varieties: 'Rancocas', 'Pemberton' and 'Scammel'; late varieties: 'HBS 46', 'Bluecrop', 'Ivanhoe', 'Kengrape', 'Concord' and 'Rubel'; very late varieties: 'Jersey', 'Berkeley', 'Burlington', 'Coville' and 'Herbert'.

Discussion

Earlier observations made on the highbush blueberry at the Institute of Horticulture (VAARAMA 1950 a, 1950 b, 1953, HÅRDH 1959) were confirmed in many respects by the results of this study. In spite of the optimism inspired by the first experiences with the highbush blueberry, it is not yet suitable for cultivation in Finland. It not only demands unusual soil conditions but is also susceptible in Finland to damage by frost and to the cancer caused by the fungus *Fusicoccum putrefaciens* Shear. Precisely these factors are responsible for the poor results obtained with trial crops.

A primary condition of economically rewarding cultivation is a sufficiently large and high-quality annual fruit yield. There is no doubt that the highbush blueberry can produce sufficiently high-quality fruit in Finland. For example in storage trials at the Institute of Horticulture its berries have been found particularly suitable for deep-freezing. The berries are also sufficiently large, since even in the varieties with the smallest fruit they are more than three times as large as those of the Finnish blueberry (*V. myrtillus* L.). In most of the varieties the fruit has a pleasant taste, although its flavour is not as strong as that of Finnish blueberries. On the other hand, Finnish taste habits seem to differ from the American. As in earlier tests (VAARAMA 1950 a), three well-known varieties were placed in the following order of merit at a tasting test performed in 1967: 'Rancocas', 'June', 'Atlantic'. In some American publications this order was completely reversed (DARROW, WILCOX and BECKWITH 1944, DARROW and MOORE 1962).

On average, the fruit yield was rather small. In the poorer varieties it was very small, and even in the best varieties it varied so widely that it is doubtful whether their cultivation in Finland can be an economic proposition. The level of the fruit yield in the varieties was observed to depend closely on several factors. This is apparent, for example, when the different characters are compared with each other (Fig. 1) with the aid of Spearman's rank correlation coefficient (SIEGEL 1956). Apart from the weight of the berries, all the other

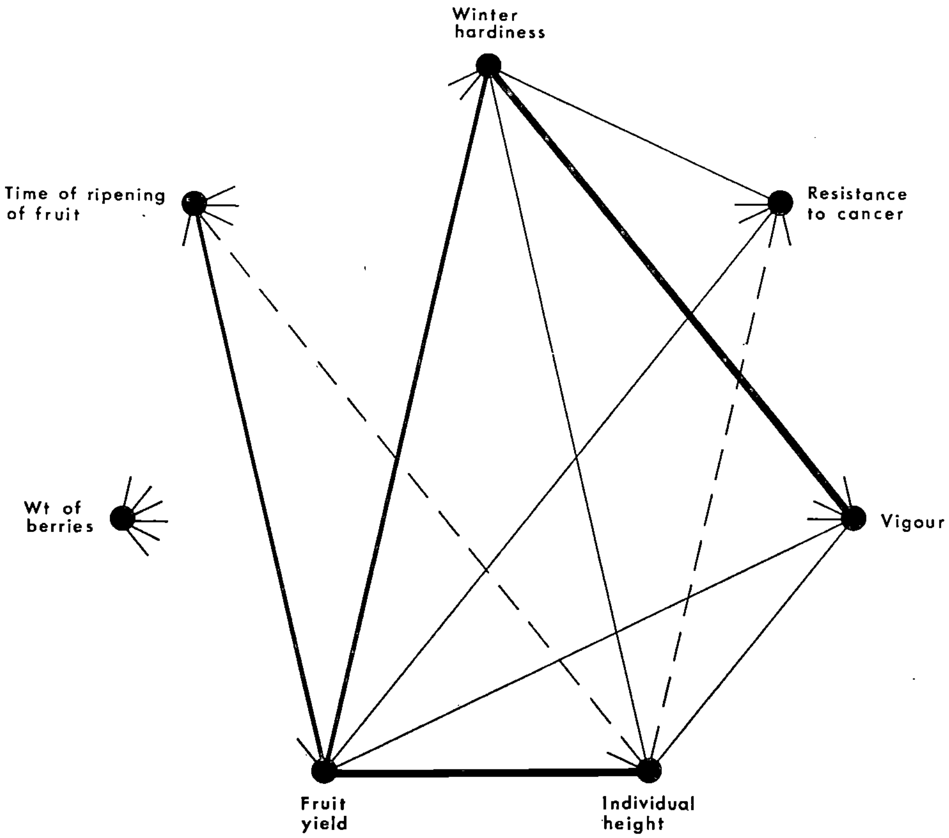

Fig. 1. Correlations between the characters of the material.
Kuva 1. Ominaisuuksien korreloituminen keskenään lajikeaineistossa.
Significance of correlation — *Korrelaation merkitsevyys:*)— —(= no correlation — *ei korrelaatiota,*)— — — — —(= orientating significance — *suuntaa-antava,*)————(= fairly significant — *jokseenkin merkitsevä,*)————(= significant — *merkitsevä,*)————(= very significant — *hyvin merkitsevä.*

characters investigated were correlated with the amount of the fruit yield at a higher or lower level of significance. The winter hardiness of the varieties is reflected either directly (r_S = 0.71, t = 3.94**, n = 17), or through other properties, in the amount of the yield. Varieties that overwinter well are particularly vigorous (r_S = 0.82, t = 5.55***, n = 17) and thus of course also productive (r_S = 0.52, t = 2.38*, n = 17). On the other hand, both winter hardiness and vigour were observed to be positively correlated with the height of the individuals (r_S = 0.54, t = 2.50*, n = 17; r_S = 0.58, t = 2.75*, n = 17), and tall-growing varieties were observed to give very significantly (r_S = 0.78, t = 4.81***, n = 17) greater yields than low-growing varieties. However, it is evident that the individual height is to a very great degree a hereditary property of the varieties. Winter hardiness and resistance to cancer are also correlated with each other to a certain extent (r_S = 0.60, t = 2.91*, n = 17). The blueberry cancer infects all the varieties very heavily so that although its general influence is very strong, its effect is less apparent than might be expected when considered in relation to the fruit yields of the individual varieties (r_S = 0.60, t = 2.87*, n = 17). The effect of the time of ripening on the fruit yields is such

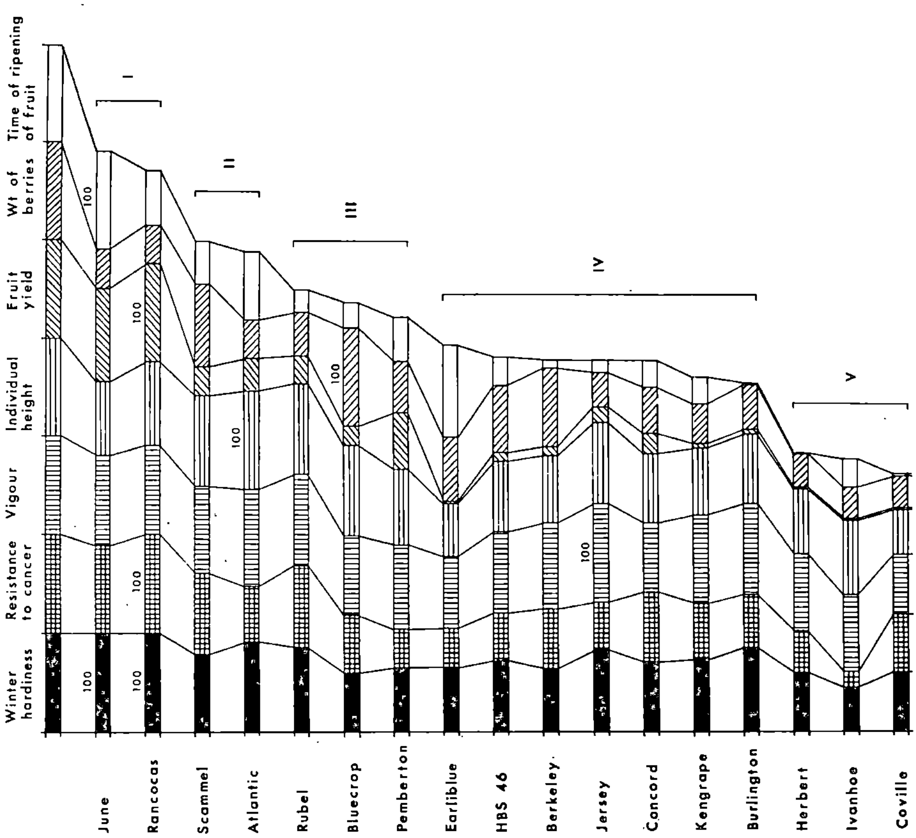

Fig. 2. The varieties arranged in order of merit according to the sum of the comparative number of the characters. The comparative numbers of 100 was assigned for the highest value of each character.

Kuva 2. Ominaisuuksien vertailulukujen summana laadittu lajikkeiden paremmuusjärjestys. Kunkin ominaisuuden kohdalla on parhaalle arvolle annettu vertailuluku 100.

that early varieties are significantly (r_S = 0.64, t = 3.30**, n = 17) more productive than late varieties, whose berries do not always have time to ripen under Finnish conditions.

An attempt was made to assess the merit of the varieties on the basis of the seven characters examined. The varieties were arranged in order of merit in accordance with the sum of the comparative numbers awarded for the different characters (Fig. 2). The comparative number 100 was given for the highest value of each character and proportionate numbers were calculated for the other values. Thus equal emphasis was laid on all the characters and a completely true picture is certainly not obtained. When assessed on this basis, the varieties may be divided into five groups. 'June' and 'Rancocas' in the first group are clearly more suitable for cultivation than the others. Compared with all the other varieties, they are at least satisfactory in respect of their winter hardiness, resistance to cancer, vigour, height, productivity and earliness. The size of their berries is the only character in which they are clearly inferior to certain other varieties. 'Scammel' and 'Atlantic' in the second group, and 'Rubel', 'Bluecrop' and 'Pemberton' in the third also deserve consideration, especially from the point of view of breeding, although their fruit yield is clearly inferior to that of the first group. The tall-growing habit of 'Atlantic' is advantageous for the harvesting of the fruit. The berries of 'Bluecrop' are clearly larger than those of the other varieties. In some years the fruit yield of 'Pemberton' may rise to the level of that of 'Rancocas' and 'June', but its rather poor winter hardiness and resistance to blueberry cancer cause wide variations in the harvest. Of the members of the fourth group, mention need be made only of 'Jersey', which was judged to be the most vigorous of all the varieties.

Owing to the wide variations in fruit yield caused by various factors, even the best of the varieties does not offer the possibility of commencing economically rewarding cultivation in Finland. However, systematic breeding has been undertaken at the Institute of Horticulture with the aim of developing varieties that are better suited to the climatic conditions of Fennoscandia, attempts being made to cross the highbush blueberry with native *Vaccinium* species (ROUSI 1963, 1966, 1967, HIIRSALMI 1968, 1969, 1971). Successful crosses were made with the bog blueberry, *V. uliginosum* L., which has the same tetraploid chromosome number as the highbush blueberry.

The first crosses between the bog blueberry and the highbush blueberry varieties 'Rancocas' and 'Pemberton' were made in summer 1961. Although the F_1 generation did not contain any individuals suitable for cultivation, the attempt to utilize the gene pool of the bog blueberry was continued, and each year from 1965 onwards back-crosses were performed with highbush blueberry varieties in addition to new primary crosses. The progeny of the back-crosses contained some individuals which were quite equal to the best of the highbush blueberry varieties in respect of most of the characters investigated here. Moreover, their winter hardiness and resistance to cancer appeared to show a clear improvement. So far, the most suitable progeny has been obtained from the cross 'Bluecrop'× (*V. uliginosum* ×'Rancocas'). There is thus good reason to believe that development of new varieties that have been strengthened by the gene pool of the bog blueberry and are better suited to conditions at northern latitudes will make it possible to commence the practical cultivation of the blueberry in Finland.

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SELOSTUS

Pensasmustikan lajikekokeista Suomessa

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Piikkiössä sijaitsevaan Puutarhantutkimuslaitokseen tuotettiin ensimmäiset pensasmustikan taimet jo keväällä 1947. Kokeissa on tähän mennessä ollut mukana yli 20 lajiketta. Tarkoituksena on paitsi selvittää eri lajikkeiden viljelykelpoisuus Suomen olosuhteissa myös löytää ne lajikkeet, joista todennäköisimmin voidaan jalostamalla kehittää viljelykelpoisia.

Ensivaikutelmien luomasta optimismista huolimatta ei pensasmustikka ole toistaiseksi kehittynyt viljelykasviksi Suomessa. Paitsi sitä, että pensasmustikka vaatii maaperälliset erikoisolosuhteet, se on meillä altis talvivaurioille ja *Fusicoccum putrefaciens* Shear -sienen aiheuttamalle syöpätaudille. Juuri nämä tekijät ovat osaltaan vaikuttaneet koeviljelystä saatuihin heikkoihin kokemuksiin.

Laadullisesti pensasmustikka tuottaa Suomessakin hyviä marjoja. Niiden maku on useimmilla lajikkeilla miellyttävä, ja ne soveltuvat erinomaisesti pakastukseen. Marjakoko on myös riittävä. Sadon määrä sen sijaan on jäänyt useimmilla lajikkeilla hyvin pieneksi, ja parhaillakin lajikkeilla satovaihtelut ovat olleet huomattavat. Marjakokoa lukuun ottamatta kaikilla tutkituilla ominaisuuksilla, talven- ja syövänkestävyydellä, elinvoimaisuudella ja yksilökorkeudella sekä marjojen kypsymisen aikaisuudella, on havaittu olevan enemmän tai vähemmän merkitsevä vaikutus sadon määrään. Toisaalta talvenkestävyyden vaikutus ilmenee useimmissa muissa ominaisuuksissa.

Kaikki koevuodet huomioiden ovat varmimpia talvehtijoita olleet lajikkeet 'June', 'Rancocas' ja 'Atlantic'. 'Rancocas' on kestänyt parhaiten syöpätautia, 'Jersey' puolestaan on ollut elinvoimaisin ja 'Atlantic' selvästi korkeakasvuisin. Satoisimpia lajikkeita ovat olleet 'Rancocas', 'June', 'Pemberton' ja 'Atlantic' sekä suurimarjaisin 'Bluecrop'. 'June' ja 'Earliblue' ovat hyvin aikaisia lajikkeita, 'Atlantic' on aikainen lajike sekä 'Rancocas', 'Pemberton' ja 'Scammel' keskiaikaisia lajikkeita. Kaikki seitsemän ominaisuutta huomioon ottaen lajikkeet 'June' ja 'Rancocas' ovat selvästi muita viljelykelpoisempia.

Paremmin ilmasto-olosuhteisiimme sopeutuvien lajikkeiden kehittämiseksi Puutarhantutkimuslaitoksessa suoritetaan jalostustoimintaa pyrkimällä risteyttämään kotimaisia *Vaccinium*-lajeja pensasmustikkalajikkeiden kanssa. Vain juolukkaa on onnistuneesti käytetty risteytyksiin. Edullisimman jälkeläistön on toistaiseksi tuottanut risteytys 'Bluecrop' × (juolukka × 'Rancocas'). On täysin perusteltua uskoa, että käytännön pensasmustikan viljelyyn voidaan Suomessakin päästä käyttämällä uusia juolukan geenivaroin vahvistettuja, pohjoisiin olosuhteisiin soveltuvia lajikkeita.

ANNALES AGRICULTURAE FENNIAE, VOL. 12: 200—206 (1973)

Seria AGROGEOLOGIA ET -CHIMICA N. 66 — Sarja MAA JA LANNOITUS n:o 66

MAAN LYIJYSAASTUMINEN SULATTAMON YMPÄRISTÖSSÄ TIKKURILASSA

RAIMO ERVIÖ ja ESKO LAKANEN (†)

ERVIÖ, R. & LAKANEN, E. (†) 1973. **Maan lyijysaastuminen sulattamon ympäristössä Tikkurilassa.** [Lead contamination of soil in the environment of a smeltery in South Finland.] Ann. Agric. Fenn. 12: 200—206.

Total and ammonium acetate/EDTA-soluble lead was analysed from cultivated and forest soils at 104 sites at Tikkurila, 15 km north of Helsinki, in the environment of a lead smeltery. For comparison, samples were taken at 38 sites 8 to 33 kilometres from Tikkurila. Soluble lead was extracted by acid ammonium acetate-EDTA solution (0.5 *M* CH_3COOH-, 0.5 *M* CH_3COONH_4- and 0.02 *M* EDTA; pH 4.65) (LAKANEN and ERVIÖ 1971 b).

In the plough layer, an average of 378 total and 212 mg extractable Pb/litre of soil was found at a distance of less than 500 m from the smeltery. This was 35 times more than was found in samples taken for comparison 8—33 km from the smeltery, and about 70 times more than is found in normal field soil in the Finnish countryside. In grassland soils, twice as much lead was found in the surface layer (0—2.5 cm) as in the plough layer, (0—20 cm). Between the years 1960 to 1970 the extractable lead content in the plough layer at a distance of 1 200—1 700 m from the smeltery increased nearly 140 per cent.

In the litter layer of surface forest soil (0—2.5 cm), as much as 25 000 mg extractable Pb/litre of soil was found on a site 100 m from the smeltery, corresponding to 158 000 ppm. Furthermore, at a distance of 2 800 m, 47 mg extractable Pb showing distinct soil contamination was found in the surface layer. The ratio of extractable Pb to total Pb in the soil became greater as the degree of lead contamination increased. In forest soil contaminated lead is for the most part immobilised in the 0—10 cm layer.

Alustavissa tutkimuksissa (LAKANEN ja ERVIÖ 1971 a) todettiin erään lyijynsulattamon ympäristön lyijysaastuminen ja sen laajuudesta saatiin viitteitä. Alueelta vuonna 1970 suunnitelmallisesti otettujen maanäytteiden tässä esitettävät analyysitulokset antavat tarkemman kuvan maaperään ilman kautta joutuneen lyijyn määrästä ja sijainnista maan pintakerroksissa.

Tutkitun alueen lyijynpäästöä ovat Työterveyslaitoksen syksyllä 1970 tekemien havaintojen perusteella selvittäneet myös LAAMANEN ja RYHÄNEN (1971). Tutkimustulokset tukevat toisiaan.

Aineisto ja menetelmät

Lyijynsulattamon ympäristöstä 150—3 600 metrin etäisyydeltä koottiin maanäytteet 104 pisteestä viljelymailta ja 11 pisteestä metsämailta sekä vertailunäytteiksi 32 viljely- ja 6 metsämaanäytettä lähiseudulta, sulattamon vaikutusalueen ulkopuolelta (8—33 km Tikkurilasta).

Viljelymaista otettiin erikseen kyntökerroksen (0—20 cm) ja jankon (20—40 cm) näytteet sekä osasta heinänurmien näytekohtia lisäksi 0—2.5 cm:n pintakerros erikseen ja eräistä vielä 40—60 cm:n pohjamaakerros. Metsämailta koottiin kustakin pisteestä kuuden eri kerroksen näytteet (0—2.5, 2.5—5, 5—10, 10—15, 15—20 ja 20—40 cm). Maanäytteiden maalaji oli pelloissa savea 68, hietaa tai hiekkaa 23 ja eloperäistä maalajia 13 tapauksessa, ja vertailumaanäytteet olivat savea 25, hietaa 5 ja eloperäistä maata 2 tapauksessa. Metsämaiden podsolimaannoksen pintakerroksena oli kangashumusta, jonka paksuus vaihteli 2.5—10 cm, ja pohjamaana hietaa tai hiekkaa. Tihein näyteverkosto oli sulattamon koillis— itä-kaakkoispuolella, jossa Maatalouden tutkimuskeskuksen viljelymaat sijaitsevat. Osa tutkituista näytteistä, lännessä 4 km:n päässä ja itäkoillisessa 1.5 km:n päässä, osuu toisten lyijyä käsittelevien sulattamojen lähialueille, joten maanäytteiden lyijypitoisuuksissa näkyy myös näiden sulattamojen saastuttava vaikutus.

Liukoinen lyijy uutettiin hapanammoniumasetaatti-EDTA-liuoksella (0.5 M CH_3COOH-, 0.5 M CH_3COONH_4- ja 0.02 M EDTA -vesiliuos; pH 4.65) (Lakanen ja Erviö 1971 b). Lyijy määritettiin uutteesta atomiabsorptiospektrofotometrilla (Techtron AA-4) suoraan tai uuttaen ensin pyrrolidiiniditiokarbamaattina metyyli-isobutyyliketoniin (Lakanen 1962). Kokonaislyijy määritettiin spektrografisesti (ARL 2m hilaspektrografi) (Lappi ja Mäkitie 1955) ja/tai atomiabsorptiospektrofotometrisesti. AA-määritystä varten tuhka liuotettiin HF- + $HClO_4$- ja HCl-käsittelyllä. Lyijy uutettiin pyrrolidiiniditiokarbamaattina metyyli-isobutyyliketoniin.

Maan lyijypitoisuus on ilmaistu mg Pb/l maata, kuten maan ravinteidenkin, mikä on tarkoituksenmukaisempaa kuin ilmaisutavan ppm (miljoonasosa) eli mg Pb/kg maata käyttäminen, koska suomalaisten maalajien tilavuuspainot poikkeavat ratkaisevasti toisistaan.

Tulokset

Viljelymaat

Taulukon 1 kokonais- ja liukoisen lyijyn pitoisuuksista ja niiden keskinäistä suhdetta kuvaavista prosenttiluvuista havaitaan liukoisen lyijyn kuvastavan paremmin maan saastumista kuin kokonaispitoisuuksien. Kun vertailunäytteiden liukoisen lyijyn määrä on 14—16 prosentin luokkaa kokonaislyijystä, on vastaava osuus saastuneella alueella, alle 0.5 km:n etäisyydellä sulattamosta, pintamaassa 56 % ja pohjamaassakin 40 %. Tämän vuoksi käsitellään tässä tutkimuksessa maan saastumisastetta ensi sijassa liukoisen lyijyn pitoisuuksien pohjalta.

Sulattamon ympäristössä aina 3.6 km:n säteellä tutkittujen peltomaiden muokkauskerroksen lyijypitoisuuden todettiin olevan varsin korkea. Taulukossa 1 analyysitulokset on ryhmitelty sulattamon piipusta lasketun etäisyyden mukaan.

Alle viidensadan metrin säteellä otettujen 10 maanäytteen liukoisen lyijyn keskiarvo 212 mg Pb/l maata on noin 35-kertainen verrattuna näyteryhmään, joka edustaa lähikuntien tilannetta 8—33 km:n etäisyydellä tutkimuskohteesta. Tämä keskiarvo, 5.7 mg Pb/l maata, on taas noin kaksinkertainen verrattuna Uuraisten kunnasta Keski-Suomesta saatuihin, ilmeisesti täysin luonnontilaisiin arvoihin 2.5 ja 3 mg. Sulattamon piipusta 130 m:n päästä saatu korkein yksittäinen arvo 985 mg on jopa 350-kertainen Uuraisten arvoihin verrattuna.

Taulukko 1. Viljelymaan lyijypitoisuus eri etäisyyksillä sulattamosta (Suluissa vaihteluväli).

Table 1. Average lead contents of cultivated soils at various distances from the smeltery.

Etäisyys *Distance*	Näytteitä kpl *No. of samples*	Lyijyä mg/l maata — *mg Pb/litre of soil*					
		Depth 0—20 cm			*Depth* 20—40 cm		
		Kokonaismäärä *Total*	Liukoinen *Extractable*	Liukoista % kokonaismäärästä *Extractable Pb per cent of total*	Kokonaismäärä *Total*	Liukoinen *Extractable*	Liukoista % kokonaismäärästä *Extractable Pb per cent of total*
0— 490 m	10	378	211.6 (53—985)	56	40	16.4 (2—89)	40
500— 990 m	30	85	32.5 (11—61)	38	41	9.1 (1—30)	22
1000—1990 m	38	77	24.9 (10—73)	32	39	7.8 (2—22)	20
2000—3600 m	21	67	22.3 (8—43)	33	33	5.9 (2—18)	18
8— 33 km	32	36	5.7 (2—10)	16	32	4.0 (0.5—8)	13
Uurainen *Central Finland*	2	20	2.8 (2.5—3)	14	17	1.2 (1—1.3)	7

Huippukorkeat maan Pb-pitoisuuden arvot rajoittuvat alle 500 metrin etäisyydelle sulattamosta. Kuten taulukosta 1 ilmenee, putoaa viljelymaan keskimääräinen liukoisen lyijyn pitoisuus tämän etäisyyden ulkopuolella jo noin 30 milligrammaan, pysyen kuitenkin muutaman kilometrin etäisyydelle noin nelinkertaisena ympäristökunnista otettujen vertailunäytteiden pitoisuuksiin verrattuna.

Jankon (20—40 cm) liukoisen lyijyn pitoisuudet ilmentävät nekin muokkauskerroksen saastumista. Muokkauskerroksesta on joutunut jankkokerrokseen lyijyä sitä enemmän, mitä runsaammin sitä on pintamaassa ollut. Jankon pitoisuudet ovat kuitenkin alhaisia pintamaan pitoisuuksien rinnalla, 0—490 m:n etäisyydellä sulattamosta keskimäärin kolmastoista- ja 2 000—3 600 m:n etäisyydellä viidesosa. Viimeksi mainitulla etäisyydellä jankonkin liukoisen lyijyn pitoisuus yltää lähes ympäristökuntien pintamaiden Pb-määrän tasolle.

Osasta näytepaikkoja, heinänurmilta, erikseen otettu 2.5 cm:n pintakerros (taulukko 2) sisältää liukoista lyijyä keskimäärin kaksinkertaisen määrän verrattuna koko muokkauskerroksen pitoisuuteen. Näiden useita vuosia kyntämättä olleiden näytekohtien tilanne osoittaa sen, että lyijy on joutunut maahan laskeumana. Samasta taulukosta ilmenee edelleen yhdeksän näytekohdan keskiarvoista, miten pohjamaan (40—60 cm) lyijypitoisuus 3.1 jää miltei kolmanteen osaan jankon (20—40 cm) pitoisuudesta 8.4 mg/l. Ensinmainittu luku edustanee jotakuinkin luonnontilaista lyijytasoa.

Taulukko 2. Nurmien erisyvyisten maakerrosten keskimääräinen lyijypitoisuus 0.2—3.6 km:n etäisyydellä sulattamosta. (Suluissa vaihteluväli).

Table 2. Average lead contents at various depths of grassland soils at 0.2—3.6 km distance from the smeltery.

Näytepisteiden lukumäärä *No. of sites*	Liukoista lyijyä, mg/l maata *Extractable Pb, mg/litre of soil*			
	0—2.5 cm	0—20 cm	20—40 cm	40—60 cm
17	80.6 (13—290)	42.9 (10—183)	10.8 (2—24)	
9		52.1 (11—188)	8.4 (1—24)	3.1 (0.5—8)

Viljelymaiden lyijyn lisääntymistä viimeisellä vuosikymmenellä kuvaavat taulukon 3 lyijyarvot, jotka ovat kahdesta eri kenttäkokeesta, ja kukin arvo edustaa 8 muokkauskerroksen maanäytteen keskiarvoa. Ensimmäisen kokeen maan lyijypitoisuus on kasvanut kymmenessä vuodessa 136 % ja jälkimmäisen 138 %. Vaikkakin lyijyn muuttumisella vaikealiukoiseen muotoon maanäytteiden varastoinnin aikana, mitä ei ole voitu selvittää, olisi vaikutusta tulokseen, voisi se merkitä vain pientä osaa todetusta lyijymäärän kasvusta.

Taulukko 3. Maan lyijypitoisuuden lisääntyminen Tikkurilassa viimeisen vuosikymmenen aikana.
Table 3. Increase in lead contamination of soils at Tikkurila during the last decade.

Site	Liukoista lyijyä mg litrassa maata *Extractable Pb mg/litre of soil* Vuosi — *Year* 1960	1964	1970
Kenttäkoe 1200 m sulattamosta pohjoiseen *A field trial 1200 m from the smeltery*	9.6	12.5	22.8
Kenttäkoe 1700 m sulattamosta pohjoiseen *A field trial 1700 m from the smeltery*	3.9	—	9.2

Metsämaat

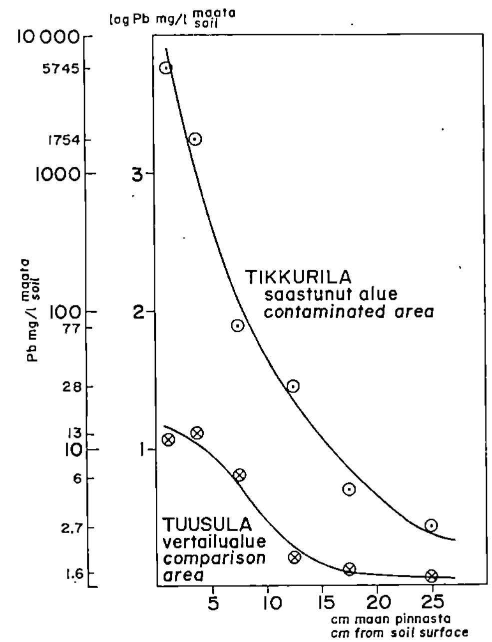
Tutkittujen metsämaiden kunkin näytekohdan lyijyarvot on esitetty kerroksittain taulukossa 4. Sulattamosta eri ilmansuuntiin suuntautuvien näytteenottolinjojen välillä on selvä tasoero pintakerrosten lyijypitoisuuksissa, niin että pohjois-koilliseen suuntautuvalla linjalla arvot ovat 9—2 -kertaisia itä-kaakkoislinjaan verrattuna. Tämä johtunee siitä, että koillinen suunta jää vallitsevien tuulten alapuolelle sulattamoon nähden.

Luonnontilassa olleet metsämaiden pintakerrokset kertovat selkeästi niihin ilman kautta laskeutuneen lyijyn määrän. Sulattamon piipusta vain 100 metrin päässä pohjois-koilliseen olevan pisteen huippuarvo 25 000 mg/l maata on saatu karikekerroksesta, jonka tilavuuspaino on 0.16. Tämä arvo merkitsee noin 158 000 ppm:n eli miltei 16 %:n pitoisuutta. Vielä 2 800 metrin etäisyydeltä sulattamosta otetun näytesarjan pintakerroksen, kangashumuksen, lyijymäärä 47 mg on nelinkertainen kuuden Uuttamaata edustavan vertailupisteen keskiarvoon 12.3 verrattuna. Lyijyllä saastuneen alueen rajaa ei siis vielä tällä etäisyydellä saavutettu.

Taulukko 4. Metsämaiden lyijypitoisuus sulattamon ympäristössä ja vertailupisteissä lähikuntien alueella.
Table 4. Lead contents of forest soil in the vicinity of the lead-smeltery (above) and in neighbouring communes (below).

Syvyys *Depth*	Liukoinen Pb, mg/l maata — *Extractable Pb, mg/litre of soil* Itä-kaakko — *East-southeast* 100 m	300 m	550 m	800 m	1350 m	1600 m	2800 m	Pohjois-koillinen — *North-northeast* 100 m	200 m	600 m	1300 m
0—2.5 cm	2792	1450	316	111	167	130	47	25361	5745	2343	355
2.5— 5 »	867	1662	161	71	48	62	14	16577	1754	509	192
5—10 »	315	420	74	27	14	8	8	6793	77	29	26
10—15 »	56	154	10	10	4	4.3	3.3	458	28	14	10
15—20 »	31	32	5	2.5	2.5	4.5	1.9	36	7	3	1.8
20—30 »	1.5	11	3.5	2	2	2	2.2	9	2.7	—	1.8

Syvyys *Depth*	Vertailupisteet — *Sites for comparison* Ilmansuunta — *Quarter* ESE	N	N	E	WSW	SSW	Keski-arvo *Mean*
	Etäisyys — *Distance* 8 km	10 km	15 km	23 km	33 km	33 km	
0—2.5 cm	19	9	12	10	12	12	12.3
2.5— 5 »	14	8	13	7.4	11	12	10.9
5—10 »	8	6.5	6.2	4	2.4	8	5.8
10—15 »	6.4	4.7	1.6	4.1	1.1	1.8	3.3
15—20 »	5	4.9	1.3	2.2	2.5	2.1	3.0
20—30 »	2.1	1.3	0.5	1.3	2.8	1.4	1.6



Kuva 1. Metsämaan liukoisen lyijyn pitoisuus kerroksittain 200 m:n etäisyydellä sulattamosta (ylempi käyrä) ja vertailualueella (alempi käyrä).

Fig. 1. Extractable lead contents of various layers in forest soils at a distance of 200 m from the smeltery (upper curve) and in the control area 15 km from the smeltery (lower curve).

Näytepistesarja osoittaa, missä suhteessa lyijypitoisuus laskee sulattamosta etäännyttäessä. Linjan itä-kaakko näytekohtien 1 350 ja 1 600 m alenevan sarjan positiiviset poikkeamat 167 ja 130 mg johtunevat tällä alueella sijaitsevan kahden romuvaraston sulatusuunien lisäsaastutuksesta.

Ilmasta tullut lyijy on suureksi osaksi jäänyt aivan maan pintakerrokseen (taul. 4). Kuvassa 1 on esitetty sama asia kahdella käyrällä siten, että pitoisuusarvot pystyakselilla on muunnettu logaritmisiksi esityksen mahdollistamiseksi. Ylempi käyrä edustaa Tikkurilan saastunutta maata 200 m pohjoiskoilliseen sulattamosta ja alempi käyrä ”normaalia” tapausta Tuusulasta, 15 km pohjoiseen Tikkurilasta. Pääosa lyijystä on pysynyt noin 10 cm:n pintakerroksessa. Lyijyn liikkuminen maassa alaspäin on siten suhteellisen vähäistä, vaikka saastutusta lienee tapahtunut koko sulattamon olemassaolon eli lähes 40 vuoden ajan, ja vaikka metsämaiden maalaji on hiekkaa ja hietaa, missä maan nestevirtaukset alaspäin pääsevät helposti tapahtumaan.

Tulosten tarkastelu

Eri puolilla Suomea sijaitsevien koeasemien 406 peltomaanäytteen keskimääräiseksi lyijypitoisuudeksi saatiin 3.2 mg/l maata (Maantutkimuslaitoksen julkaisematon aineisto). Tähän arvoon verrattuina Tikkurilan viljelymaiden Pb-arvot 8—985 osoittavat melkoista saastumista, ja ympäristökunnistakin Uudeltamaalta saatu keskiarvo 6.0 mg lyijypitoisuuden kaksinkertaistumista muuhun Suomeen verrattuna. Tikkurilasta saadut liukoisen lyijyn arvot ovat huomattavan suuria maaperämme kokonaislyijyn pitoisuuksiinkin verrattuina. VUORINEN (1958) on todennut 3 500 peltomaanäytteen keskiarvoksi 16 mg/kg ja MÄKITIE (1961) kokonaislyijymäärän vaihteluksi kivennäismailla 6—60 ja eloperäisillä mailla 0—40 mg/kg.

Alue, jolle lyijy Tikkurilassa on ilman kautta saastutuslähteestä levinnyt, on varsin laaja. Etäisimpien lähialueen näytteiden, peltomaa 3 600 m ja metsämaa 2 800 m tehtaasta, antamat lyijyarvot osoittautuvat vielä selvästi normaaleista poikkeaviksi. Tällä perusteella havaittavasti saastunut alue on ainakin 40 km². Lyijyä on levinnyt enemmän vallitsevien lounais- ja etelätuulten kuin länsi- ja luoteistuulten alapuolelle, kuten taulukosta 4 havaitaan. Alle 500 metrin etäisyyden keskimääräinen kokonaislyijyarvo 378 mg/l merkitsee, että peltomaan muokkauskerroksessa on 756 kg lyijyä hehtaarilla.

Metalliteollisuusalueilla on monissa tutkimuksissa maan pintakerroksiin havaittu rikastuneen normaaleihin pitoisuuksiin nähden kymmenen- ja jopa tuhatkertaisia määriä lyijyä. Erään lyijynsulattamon ympäristöstä Neuvostoliitosta on todettu 500 metrin etäisyydellä maan sisältäneen lyijyä 11 560 mg/kg (SMOKOTNINA 1962). Lyijy- ja sinkkikaivos- ja sulatuslaitosalueella Jugoslaviassa oli 200 metriä tehtaasta 3—4 cm:n pintakerroksesta AL-menetelmällä uutettua lyijyä 12 057 mg/kg ja totaalilyijyä 24 880 mg/kg (DJURIC ja KERIN 1971), mitkä pitoisuudet Tikkurilassa lähinnä sulattamoa sijainneen metsämaan näytepisteen kohdalla ylitettiin. Walesissa ovat ALLOWAY ja DAVIES (1971) löytäneet lyijykaivosseudun jokien tulva-alueen maasta lähes 3 000 mg/kg totaalilyijyä. BURKITT ym. (1972) totesivat Englannissa Bristolin lähellä lyijynsulattamon ilman kautta aiheuttaman saastutuksen näkyvän vallitsevien tuulten alapuolella vielä 8.8 km:n päässä 334 mg/kg Pb-pitoisuutena maassa.

Näyttää todennäköiseltä, että lyijyä on levinnyt jo globaalina laskeumana maaperän pintakerroksiin metalliteollisuudesta sekä lämmitys- ja polttoaineista peräisin olevana saasteena, sillä se on raudan jälkeen yleisin metalli ilmakehässä asumattomillakin seuduilla (SCHROEDER ym. 1970). Tämä selittää myös sen, että lyijy on kasautunut suhteellisesti enemmän kuin muut metallit maan pintakerrokseen (WRIGHT ym. 1955, HVATUM 1971 ja TANSKANEN 1972). HVATUM (1971) totesi lisäksi soiden 10 cm:n pintakerroksen lyijypitoisuuden olevan Etelä-Norjassa noin kuusinkertaisen Pohjois-Norjaan verrattuna.

Taulukossa 4 metsämailla esitettyä lyijyn suhteellista jakautumaa pystysuorassa suunnassa tukevat LAGERWERFFin ja SPECHTin (1970) USA:ssa ja TYLERin (1970) Ruotsissa saamat tulokset moottoriliikenteen aiheuttamasta teiden varsien maan saastumisesta. TYLER (1970) löysi metsämaasta 10 m:n etäisyydellä tiestä EDTA -liukoista lyijyä seuraavasti:

0 — 2.5 cm	175 mg/kg	10 — 20 cm	3.1 mg/kg
2.5 — 5 »	99 »	20 — 30 »	2.6 »
5 —10 »	19 »	30 — 40 »	2.3 »

Paitsi se, että lyijyä on tullut ilmakehästä, vaikuttaa sen jäämiseen maan pintakerrokseen suuresti maakerroksen laatu, sillä viljelymaiden muokkauskerros ja varsinkin metsämaiden pintakerros sisältävät runsaasti orgaanista ainesta, johon lyijyn oletetaan pidättyvän huomattavasti pysyvämmin kuin muiden maassa yleisesti esiintyvien metallikationien (TYLER 1970, MATT 1971).

Tiivistelmä

Lyijynsulattamon aiheuttamaa maan saastumista Tikkurilassa tutkittiin 340 viljely- ja metsämaanäytteen avulla. Maanäytteistä analysoitiin sekä kokonais- että hapanammoniumasetaatti/EDTA -liukoinen lyijy.

Maan lyijypitoisuudet todettiin selvästi kohonneiksi aina 3.6 km:n etäisyydelle asti, johon lähialueen näytteenotto rajoitettiin verrattaessa maanäytteiden pitoisuuksia ympäristökunnista otettujen vertailunäytteiden ja parin Keski-Suomen näytteen pitoisuuksiin.

Sulattamon välittömästä läheisyydestä saatiin erittäin korkeita lyijypitoisuuksia, pellon muokkauskerroksesta 130 m:n päästä sulattamosta 985 mg liukoista lyijyä litrassa maata ja metsämaan pintakerroksesta 100 m:n päästä jopa 25 000 mg. Suhteellisesti pahiten saastunutta ympäristö oli noin 500 metrin etäisyydelle.

Nurmien pintakerroksen (0—2.5 cm) lyijypitoisuus oli kaksinkertainen koko kyntökerroksen (0—20 cm) ja kahdeksankertainen jankon (20—40 cm) pitoisuuteen verrattuna. Varsin selvästi saasteena laskeutunut lyijy oli jäänyt metsämaanäytteiden kangashumusta sisältävään pintakerrokseen eikä ollut sanottavasti kulkeutunut 10 cm:ä syvemmälle.

Kahdella koepaikalla 1200 ja 1700 m:n päässä sulattamosta todettiin maan lyijypitoisuuden lisääntyneen vuosien 1960 ja 1970 välisenä aikana lähes 140 %.

Liukoisen lyijyn osuus kokonaislyijystä oli sitä suurempi, mitä enemmän maa oli lyijyn saastuttamaa.

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THE BROME GRASS MOSAIC VIRUS AS A CAUSE OF CEREAL DISEASE IN FINLAND

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BREMER, K. 1973. **The brome grass mosaic virus as a cause of cereal disease in Finland.** Ann. Agric. Fenn. 12: 207–214.

By means of sap transmission, several isolates were made from a virus naturally infecting wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), rye (*Secale cereale* L.), timothy grass (*Phleum pratense* L.), common bent (*Agrostis tenuis* Sibth) and couch (*Agropyron repens* (L.) Beauv.) in fields. All isolates also infected maize (Zea mays L.) and many grasses as well as some dicotyledoneous plants in greenhouse tests. The virus was readily transmitted by sap, and is probably also transmitted through soil.

Six virus isolates were compared in tests. They had about the same range of hosts. The thermal inactivation point of three isolates was +72—+74°C, and that of the other three was +76°C—+80°C. Dilution endpoints of the virus isolates varied between 1: 10 000 to 1: 50 000. The leaf sap pressed from infected barley leaves was infective after 7 but not after 14 days at a temperature of +20—+23°C. Small spherical particles of about 30 my diameter were seen in the barley leaves infected by the Vantaa isolate. The virus isolates were concluded to belong to the brome grass mosaic virus, which has not previously been recorded in Finland, on the basis of the symptoms which they caused in different host plants, their host range, and their physical properties in vitro.

Introduction

The brome grass mosaic virus was first found in the U.S.A. on a *Bromus inermis* Leyss. plant showing yellow mosaic symptoms (Mc KINNEY 1953) and in *Poa pratensis* L. in Kansas SILL and CHIU 1959).

Brome grass mosaic was also found in wild species of *Lolium* and *Hordeum* in the German Democratic Republic. There it was thought to be a new virus and was therefore given a name, ”Weidelgrasmosaik” (ÖHMANN and KREUTZBERG 1963), but later it proved to be a strain of the brome grass mosaic virus (PROLL and RICHTER 1965). RICHTER et al. (1966) also compared the German and American isolates.

The brome grass mosaic was reported on *Agropyron repens* (L.) Beauv. (VLASOV et al. 1965) and on winter wheat and *Bromus* spp. in Russia (LARINA 1968). SLYKHUIS (1967) compared isolates of the brome grass mosaic virus from the U.S.A. and Russia.

The brome grass mosaic virus had hitherto been found mainly on wild grasses or only occasionally on cereal plants, but in South

Africa it was reported to have caused serious disease in wheat and pasture grasses (v. WECHMAR 1965, v. WECHMAR and REGENMORTEL 1966). In Yugoslavia the brome mosaic virus was first found in *A. repens* (MILIČIĆ et al. 1966) but later in wheat and barley also (TOŠIĆ 1971).

The barley stripe mosaic virus was isolated in all countries by sap transmission, but in the German Democratic Republic three nematode species were found to be capable of transmitting it (SCHMIDT et al. 1963).

A few fields surveys were made in Southern Finland in the years 1971 and 1972 to observe the occurrence of cereal virus diseases.

Some wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), timothy (*Phleum pratense* L.), *Agrostis tenuis* L. and couch grass (*A. repens*) plants with faint mosaic symptoms or yellowing on their leaves collected and tested in the greenhouse to find out if viruses caused these symptoms. The brome grass mosaic virus was isolated from all these plants.

Material and methods

The six brome grass mosaic virus isolates used in tests were isolated as follows: the first, named the Vantaa isolate, from a barley plant showing faint mosaic symptoms in Vantaa, near Helsinki; the Nurmijärvi isolate from an almost symptom free barley plant in Nurmijärvi village; the Inkoo isolate from a spring wheat plant, the leaves of which were yellow though there were no clear symptoms of mosaic, in Inkoo parish: the Tenhola isolate from a barley plant with yellow mosaic on the leaves in Tenhola parish; the Perniö isolate from a barley plant with very faint mosaic diseased *A. repens* growing on the verge of a field at the University farm in Helsinki.

All isolates were propagated on barley cv. Ingrid, which was also used as a test plant in all tests.

Thermal inactivation points were determined by maintaining the sap, which had been pressed through cheesecloth, at intervals of 2°C over temperatures ranging from 70 to 80°C for ten minutes. To determine the dilution end-point, the sap, pressed through cheesecloth, was diluted with tap water.

Electron microscopic examination of the virus was made at the Electron Microscopic Institute of the Helsinki University. The crude plant sap was examined by the dip method (BRANDES 1957), dipping small cuttings of the barley leaves directly into a drop of 2 % PTA on a formvaroated grid.

Results

Symptoms and hosts

All six isolates caused clear symptoms on barley, oats, wheat, rye and maize, in many grasses and in a few dicotyledonous plants. The host plants and symptoms caused by the six virus isolates are shown in Table 1, where the plants listed were inoculated with the sap.

In the leaves of barley, oats, and wheat, the virus caused yellow or white spots and streaks which rapidly spread over the leaves formin at first a yellowish green and later bright yellow mosaic pattern (Fig. 1). In rye, the colour of the mosaic symptoms was faint. The mosaic in wheat and barley was quite similar to that caused by the wheat streak mosaic virus. In addition to the mosaic on the leaves, the infected plants were somewhat dwarfed and their heads shrivelled.

The mosaic symptoms were very clear during the 3—4 weeks following emergence,

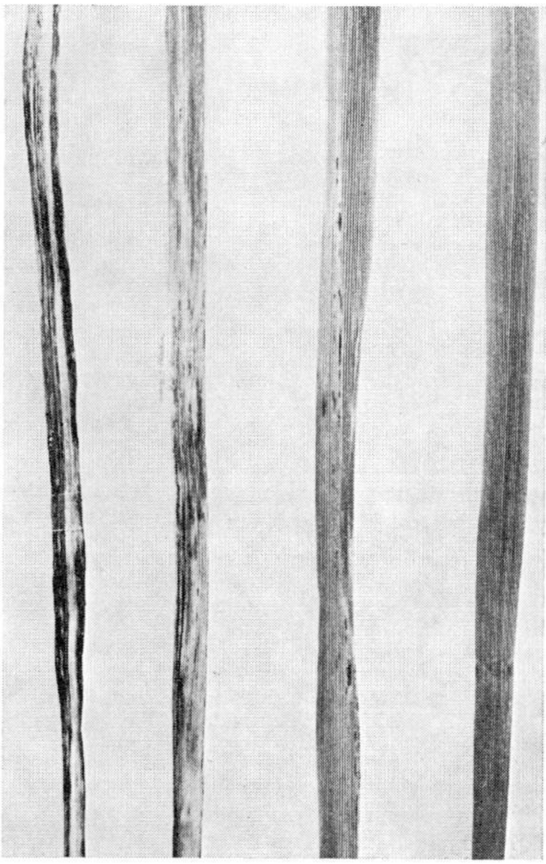

Fig. 1. Symptoms of the brome grass mosaic virus on barley leaves. The leaf on the right is healthy.

but faded later and the mosaic was often almost unrecognisable at heading time.

The symptoms were somewhat different in maize from those found in other cereals. In maize leaves, the virus at first caused local necrotic spots and lesions (Fig. 2 a); necrosis was sometimes so strong that the plants died; later, systemic mosaic appeared. The Tenhola isolate, however, did not cause any necrosis in maize.

The intensity of the symptoms varied more in grasses than in cereals and ranged from very strong yellow mosaic to very faint light green colouring. The most striking symptoms, apart from those in cereals, appeared in *A. repens*, *Bromus macrostachia* Dsf., *Lagurus ovatus* L., *Panicum miliaceum* L., *Setaria italica* (L.) Beauv and *S. macrostachia* H.B.K. On the other hand, *Agrostis tenuis* Sibth was almost symtomfree. The virus isolates could also be re-isolated from all cereals and grasses inoculated.

In addition to the cereal and grass host plants mentioned in Table 1, further grass species were inoculated only with the Vantaa isolate.

Clear symptoms were shown by the following grasses and the virus could be re-

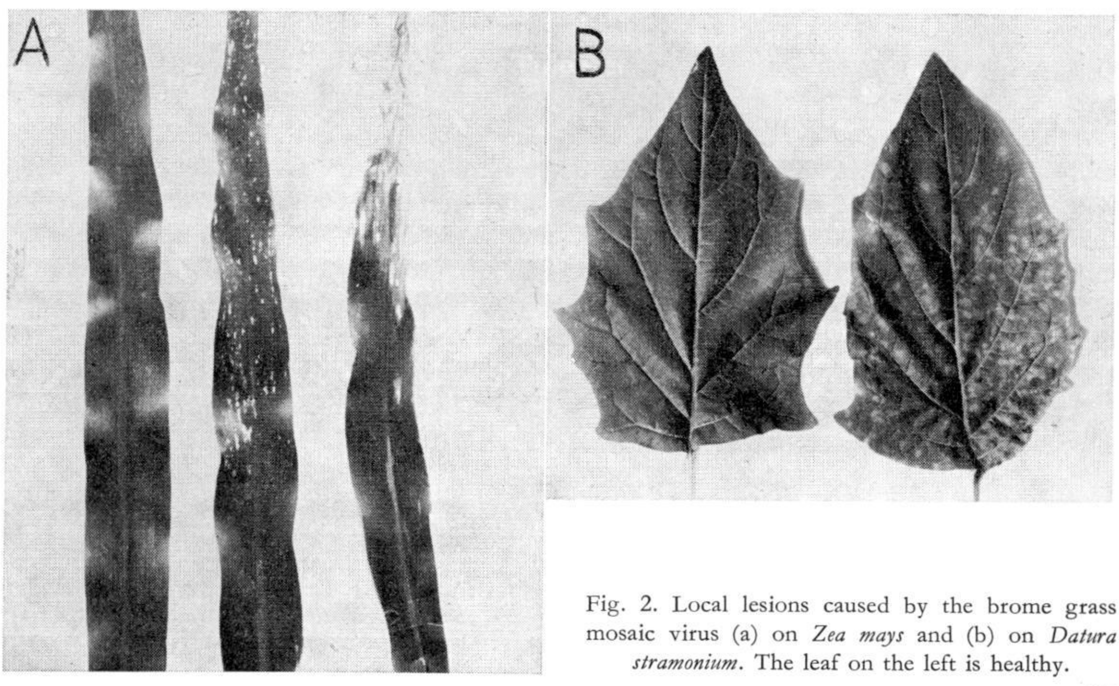

Fig. 2. Local lesions caused by the brome grass mosaic virus (a) on *Zea mays* and (b) on *Datura stramonium*. The leaf on the left is healthy.

Table 1. Reaction of the host plants to BMV-isolates.

Host plant	Vantaa isolate	Nurmijärvi isolate	Symptoms caused by the Viik isolate	Inkoo isolate	Perniö isolate	Tenhola isolate
GRAMINEAE:						
Agropyron repens (L.) Beauv.	mosaic	faint mosaic	strong yellow streaks and mosaic	strong yellow streaks and mosaic	yellow streaks	mosaic
Agrostis tenuis Sibth.	latent	latent	latent	faint mosaic	—	mild mosaic
Avena sativa L. cv. Sisu	mosaic	mosaic	mils mosaic	osaic	mosaic	mild mosaic
Bromus inermis Leyss.	mild mosac	mosaic	mild mosaic	mosaic	mild mosaic	strong mosaic
Dacrylis glomerata L.	yellow mosaic	not susceptible	mild mosaic	mosaic	mild mosaic	yellow streaks and mosaic
Festuca pratensis Huds.	latent	mosaic	yellow mosaic	mosaic	mild mosaic	mild mosaic
Hordeum vulgare L. cv. Ingrid	strong mosaic	strong mosaic	yellow mosaic	strong yellow mosaic	strong yellow mosaic	yellow mosaic
Lolium multiflorum Lam.	mosaic	mosaic	mosaic	mosaic	mosaic	mild mosaic
L. perenne L.	latent	latent	mosaic	mosaic	mosaic	mild mosaic
Phleum pratense L.	latent	latent	yellow mosaic	mosaic	mosaic	yellow streaks
Poa pratensis L.	latent	latent	mosaic	mosaic	latent	mosaic
Setaria italica (L) Beauv.	strong mosaic	latent	strong mosaic	strong mosaic	mosaic	mosaic
Triticum aestivum L. cv. Timantti	mosaic	latent	yellow streaks and mosaic	strong yellow mosaic	strong yellow mosaic	mosaic
Zea mays L. cv. U.S. 13	local necrotic spots, later systemic mosaic	local necrotic spots and systemic mosaic	local necrotic spots and systemic mosaic	local necrotic spot and mosaic	local necrotic spots and systemic mosaic	systemic mosaic
DICOTYLENAE:						
**Chenopodium amaranthicolor* Coste et Reyn.	local necrotic spots, later systemic mosaic	local necrotic spots and systemic mosaic	local necrotic spots and systemic mosaic	clorotic spots	local necrotic spots and systemic mosaic	systemic mosaic
**C. quinoa* Willd.	clorotic spots	clorotic spots	clorotic spots	clorotic spots	clorotic spots	clorotic spots
**Petunia hybrida* Vilm.	systemic mosaic	systemic mosaic	systemic mosaic	systemic mosaic	systemic mosaic	systemic mosaic
Datura metel	local ring spots	local ring spots	local ring spots	local ring spots		
D. stramonium L.	local ring spots	local ring spots	local ring spots	local ring spots		
Gomphrena globosa L.	systemic mosaic	systemic mosaic	systemic mosaic	systemic mosaic	systemic mosaic	systemic mosaic
Phaseolus vulgaris L.	local necrotic spots					

All isolates could be reisolated from all the gramineous plants mentioned in Table 1 and from the dicotylenous plants marked *

isolated from them: *Gramineae: Avena strigosa* Schreb., *Brumus adoensis* Roth., *B. erectus* Huds., *B. macrostachia*, *B. madritensis* L., *B. rigidus* Roth., *Briza minor* L., *Festuca rubra* L., *Hordeum jubatum* L., *H. marinum* Huds., *Holcus lanatus* L., *Lolium temulentum* L., *Panicum crus-galli* L., *P. miliaceum*, *Poa annua* L., *Setaria glauca* (L.) Beauv, *S. macrostachia* HBK, *Sorghum durra* Pers., *S. vulgare* Stapf.

The following dicotyledonous plants showed symptoms: *Chenopodium amaranthicolor* Coste et Reyn., *C. quinoa* Willd, *Datura metel* L., *D. stramonium* L., *Gomphrena globosa* L., *Petunia hybrida* Vilm.

Datura metel, *D. stramonium* and *Phaseolus vulgaris* L. were inoculated only with the Vantaa isolate. The virus caused local necrotic spots in *D. metel* and *D. stramonium* (Fig. 2 b) and smaller necrotic spots in *Phaseolus vulgaris* The virus could not, however, be reisolated from these plants.

All six virus isolates caused systematic mosaic in *Gomphrena globosa* and *Petunia hybrida*. The virus could also be reisolated from these plants. All six isolates caused small chlorotic spost in the leaves of *Chenopodium amaranthicolor* and *C. quinoa*. The virus could also be reisolated from *C. amaranthicolor* and *C. quinoa*.

Transmission of the virus isolates

All six isolates were readily transmitted by sap. The virus could be as easily transmitted by sap from macerated leaves or roots. The virus was also easily detected in roots only five days after inoculation into leaves.

In several tests seed — altogether about 300 seeds from barley and wheat plants infected by the Vantaa isolate — were collected and planted. None of the plants grown from this seed were infected. The virus does not seem to be transmitted by seed.

Some tests were made to determine whether the virus was transmitted through soil.

Soil was collected from a field in Viik, Helsinki, where *Agropyron repens* plants were naturally infected by the virus (Viik isolate).

After removing all visible plant debris from the soil, barley was sown in this soil. There were about 320—370 barley plants in 60 pots but only two showed typical symptoms of brome grass mosaic virus. The virus was further transmitted to barley from these two plants. It caused the same symptoms as the Viik isolate and had the same thermal inactivation point as the Viik isolate.

Several dicotyledonous and *Gramineae* plants were taken from the field where the Viik isolate of the virus occurred. These were planted in sterilized soil with healthy barley seedlings. Part of the roots and leaves of each field plant were removed before planting and used as inoculum in sap transmission to test if the plants were infected. More barley seedlings, 7 out of 110 grown in the same pots as the field plants, became infected than when barley seedlings were grown in the field soil without any plants (Table 2).

Table 2. Isolation of the brome grass mosaic virus from leaves and roots of wild plants (naturally infected by the virus) and infection of barley test plants planted in the same pot as the wild plant.

Plant species taken from the field	Virus isolated from the field plants		Barley seedlings (planted in the same pot as the field plant)
	roots	leaves	infection
Matricaria inodora	—	—	+
Taraxacum officinale	+	—	+
Taraxacum officinale	+	—	+
Agropyron repens	+	+	—
Agropyron repens	+	+	+
Agropyron repens	+	+	—
Agrostis tenuis	+	—	+
Agrostis tenuis	—	—	+
Phleum pratense	+	+	—
Phleum pratense	+	+	+
Poa annua	+	+	—
Poa annua	—	—	—
Poa annua	+	+	+
Secale cereale	—	—	—
Secale cereale	+	—	+

\+ = plant became infected
— = plant did not become infected
In Table 2 mentions only those plants from which the virus was transmitted to barley. Altogether 10 gramineous and 40 dicotylenous plants were tested in this way.

Table 3. Thermal inactivation of the virus isolates. Average results of four tests (plants infected/plants inoculated).

Isolate	Temperatures at which the leaf sap was kept for 10 minutes 72°C	74°C	76°C	78°C	80°C	Unheated control
Vantaa	5.7/14.0	0/14.0	0/17.5			18.5/18.5
Nurmijärvi	4.1/14.0	0/12.0	0/14.0			16.0/16.0
Viik	2.5/10.0	0/9.0	0/9.2			10.0/10.0
Inkoo	10.0/10.0	7.2/13.8	6.3/13.5	1/16.5	0/12.0	13.0/13.0
Perniö	13.2/15.0	6.0/10.7	0/11.2	0/11.5		14.0/14.0
Tenhola	10.0/10.0	4.0/10.2	0.3/10.0	0/11.3		11.3/11.3

Physical properties in vitro

Thermal inactivation

Thermal inactivation point was determined for each virus isolate separately, each by four tests.

The thermal inactivation points of the virus isolates varied from 72°C to 78°C (Table 3).

Dilution end-point

The dilution end-points of the virus isolates seemed to vary according to the age of the source plants and to the growing conditions of the test plants. They were usually lower in winter than in summer. The dilution end-points determined for the all virus isolates in spring were 1: 10 000—1: 50 000.

Longevity in plant sap

The sap pressed from infected barley plants was infective after 7 but not 14 days at +20—+23°C temperature. All isolates had the same longevity in vitro.

Electron microscopy

When the sap from barley leaves infected by the Vantaa isolate were examined under the Philips electron microscope with primary magnifications of 20 000, spherical particles of about 30 μ diameter were seen. These particles were not observed in the sap of the healthy barley plants.

Discussion

The brome grass mosaic virus has a very wide range of hosts (cf. McKinney 1953, Smith 1957, Öhmann-Kreutzberg 1963). This was confirmed by the Finnish virus isolates, which infected many gramineous and some dicotyledonous plants. Four Finnish isolates infected *P. hybrida*, which did not become infected by the brome grass mosaic virus used by Öhmann-Kreutzberg (1963). On the other hand, Ford et al. (1970) infected *P. hybrida* with their isolate from the U.S.A.

The brome grass mosaic virus has been easily transmitted by sap but Schmidt et al. (1963) showed that the German isolate was also transmitted by nematodes, *Longidorus macrosoma*, *Xiphinema paraelongatum*, and *X. coxi*.

In the present preliminary tests few barley plants planted with wild monocotyledoneous and dicotyledonous plants from a field where the brome grass mosaic virus occurred became infected with the virus. This seems to indicate a possibility that the Finnish virus is also transmitted by soil or, more probably, by some vector in the soil.

Three Finnish isolates had a thermal inactication point in the range +72—74°C and three +76—78°C. According to other workers also, the thermal inactication point of the brome grass mosaic virus varies greatly from +70°C to +85°C. The American and the German isolates seem to have the highest thermal inactivation points, +78.5°C (McKinney 1944) and +75°—80°C (Ford et al. 1970) in U.S.A., and +85°C in Germany (ÖHMANN-KREUTZBERG 1963).

Vantaa isolate particles measured about 30 mμ in diameter. This agrees with other workers' measurements, in which the diameter of the isometric particles varied from 22 to 33 μ (KAESBERG 1956, CHIU and SILL 1963, ÖHMANN-KREUTZBERG 1963, SCHMIDT 1967, FORD et al. 1970 TOŠIČ 1971).

It is not known how widespread the brome grass mosaic virus is in Finland, but no doubt it is not a recent introduction into this country. It has been found in several fields, at about 200 KM distance from each other. The brome grass mosaic virus also seems to occur in different isolates in this country and it has been isolated from several naturally infected cereal species and grasses in fields. *Agropyron repens* and *Phleum pratense* are very suitable round-the-year hosts for the virus, so it can remain in a field without any cereals for several years.

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SELOSTUS

Bromus-mosaiikkiviruksen aiheuttamaa viljan tautia Suomessa

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Pelloilta otetuista vehnä-, ohra-, kaura- ja ruiskasveista sekä seuraavista heinistä: timoteista, nurmiröllistä ja juolavehnästä eristettiin mehusiirrostuksella viruksia. Kaikki nämä virusisolaatit tartuttivat myös maissia, monia heiniä ja myös eräitä kaksisirkkaisia kasveja kasvihuonekokeissa. Virusisolaatit siirtyivät helposti mehussa, mahdollisesti myös maassa.

Kuutta virusisolaattia vertailtaessa niiden isäntäkasvilajistojen todettiin olevan hyvin samanlaiset. Kolmen isolaatin lämmönsietoraja oli +72—74°C ja kolmen isolaatin +76—80°C. Kaikkien isolaattien laimennusrajat olivat 1: 10 000—1: 50 000 vaiheilla. Isolaatit säilyivät infektiokykyisinä puristemehussa ainakin 7 vrk mutta eivät 14 vrk +20—23°C lämpötilassa.

Elektronimikroskoopin avulla nähtiin Vantaa-isolaatin infektoimien ohrien lehdistä kastomenetelmällä tehdyissä preparaateissa noin 30 μ läpimittaisia, pallomaisia hiukkasia.

Kaikkien virusisolaattien todettiin niiden eri isäntäkasveissa aiheuttamiensa oireiden, isäntäkasvilajistojensa ja fysikaalisten ominaisuuksien perusteella olevan Bromus-mosaiikki (Brome grass mosaic) virusta, jonka ei ole aikaisemmin todettu esiintyvän Suomessa.

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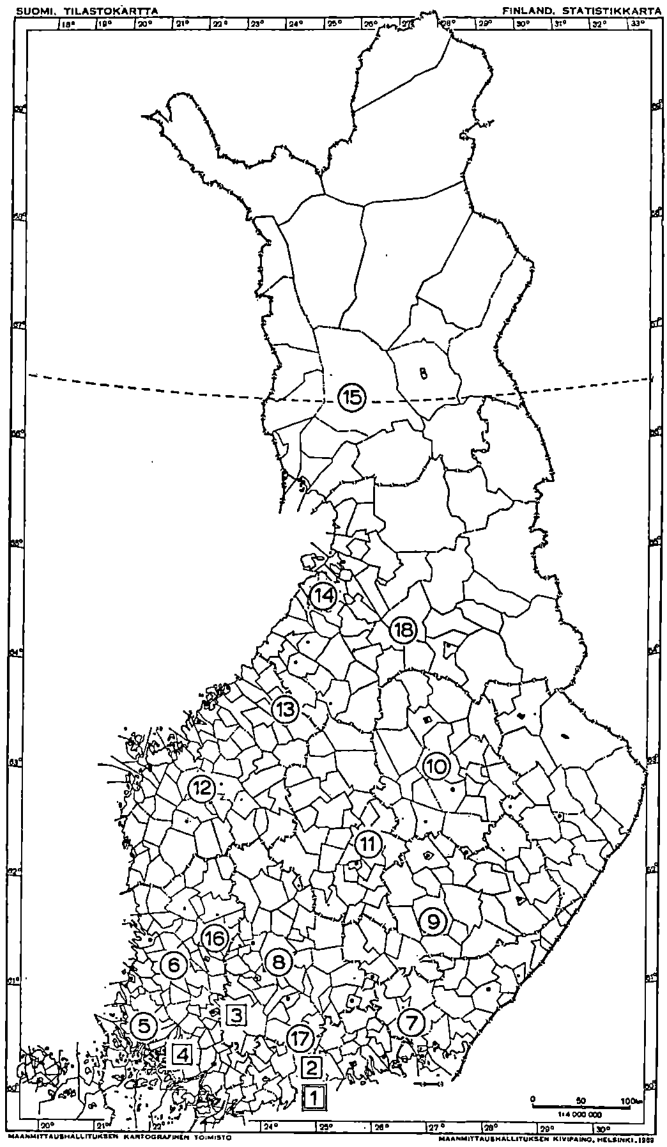

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