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ANNALES AGRICULTURAE FENNIAE, VOL. 18: 149—153 (1979)

Seria PHYTOPATHOLOGIA N. 70 — Sarja KASVITAUDIT n:o 70

STUDY OF CONTROL OF SEED-BORNE FUSARIUM IN CEREALS

JUHANI UOTI

UOTI, J. 1979. **Study of control of seed-borne fusarium in cereals.** Ann. Agric. Fenn. 18: 149—153. (Kemira Oy, SF-00100 Helsinki 10, Finland.)

Greenhouse and field trials were conducted to investigate the control of seed-borne fusarial infection with chemical seed dressings. The treatments of the seed lots infected naturally with various *Fusarium* species improved the germination of healthy seedlings. When the seeds were artificially inoculated with a pathogenic strain of *F. culmorum* (W. G. Sm.) Sacc., seed dressing also increased the percentage of healthy seedlings. With the natural, seed-borne infection, the systemic fungicides seemed to be more effective than mercury, whereas with the artificially inoculated seeds, there was no clear difference between the different chemicals. Biological control with *Trichoderma* spp. also appeared to be beneficial.

Index words: *Fusarium*, control.

INTRODUCTION

Chemical seed treatment is a common practice in cereal cultivation. Mercury seed dressings are still the most common products, although new compounds are replacing them in several countries where mercury is banned due to its toxicity (CALLAN 1975). The sales of mercury seed dressings in Finland were sufficient to cover 45 % of the total cereal area in 1977 (TIITTANEN and BLOMQVIST 1978). The harmful properties of mercury will obviously also limit its use in the near future in Finland. Systemic fungicides like benzimidazoles and thiophanates, which also exhibit wide spectrum activity (PEARSON 1978), are among the new products replacing mercury.

In the present experiments, the efficacy of mercury and some new compounds was tested with naturally infected seed and with seed artificially inoculated with a pathogenic strain of *F. culmorum* (W. G. Sm.) Sacc. Because none of the newly developed fungicides has as wide a spectrum of activity as mercury, and even mercury is ineffective against some important diseases such as loose smut, an attempt was made to develop a universal multi-compound mixture. The promising results with *Trichoderma* in the earlier study (UOTI 1976 b) also supported the further testing of biological control under field conditions.

MATERIAL AND METHODS

Natural infection

Heavily infected seed lots from the grain yield of 1972 were selected for the seed dressing trials in the greenhouse. The trials were conducted half a year after the harvest with normally dried seeds. Three barley and one oat seed lots were included. Their fusarial infection was determined as earlier described by Uoti and Ylimäki (1974). The infection was as follows:

Variety	The frequency of isolation of *Fusarium* species in %					
	F. avenaceum	*F. culmorum*	*F. poae*	*F. tricinctum*	*F.* sp.	All *Fusarium*
Pirkka-barley I .	20	4	—	—	2	26
Pirkka-barley II .	20	4	4	14	6	24
Pomo-barley ...	18	2	—	32	12	48
Hannes-oat.....	10	18	12	20	4	56

The seed lots were dressed with Täyssato, a commercial mercury product (methoxy-ethyl-mercury-chloride 22,1 g/kg) and an experimental systemic, fungicide, Bas 3 302 F (N-cyclo-hexyl-2,5-dimethyl-furan-3-carbonic acid 500 g/kg + maneb 320 g/kg). Both were used with a proportion of 200 g/100 kg seed. Pots filled with steam sterilized soil were sown with 100 seeds per pot. Four replicas were included for each trial. After four weeks of growth, the sprouted seedlings were removed and evaluated.

Artificial inoculation

Tähti-spring wheat seeds were inoculated with a pathogenic strain of *F. culmorum* as described by Uoti (1976 a). The inoculated seeds were then immediately treated with different compounds (Table 1). The seeds were sown in pots in the greenhouse and the seedlings were evaluated as above.

Table 1. Fungicide mixtures and their concentrations (%) in the greenhouse trial with artificial inoculation of *F. culmorum*.

Treatment	Imazalil	Carbendazim	Carboxin
a	—	—	75
b	14	—	—
c	—	50	—
d	7	25	—
e	3,5	12,5	37,5
f	4,7	16,7	25,0
g	5,6	20,0	15,0

In 1977 and 1978, similarly inoculated wheat seeds were sown outdoors. The following chemical treatments were included: Täyssato (mercury), Topsin M, a commercial, thiophanate-methyl product (750 g/kg) and a tri-compound mixture, 9 051/1 (imazalil 20 g/kg + carbendazim 100 g/kg + carboxin 100 g/kg) all as powder formulations. Again dosages of 200 g/100 kg seed were used. In addition to chemical treatments, the spores of *Trichoderma* spp. were used as either a seed treatment, or as a soil drench as described by Uoti (1976 b). The size of plots in the field trials was 0,5 × 2 m, and the seeds were sown with a Mini-Nipex drill. Four replicas were included for each trial. The sprouted seedlings were counted four weeks after sowing. In 1978 the seed heads were also counted before harvesting. No harvest was possible in 1977 due to the inclement weather.

RESULTS

In the seed lots with natural infection of *Fusarium* species, seed dressing increased the number of seedlings in all barley seed lots. When comparing the percentage of healthy seedlings, the beneficial effect of the chemical treatments was relatively greater, and the difference was

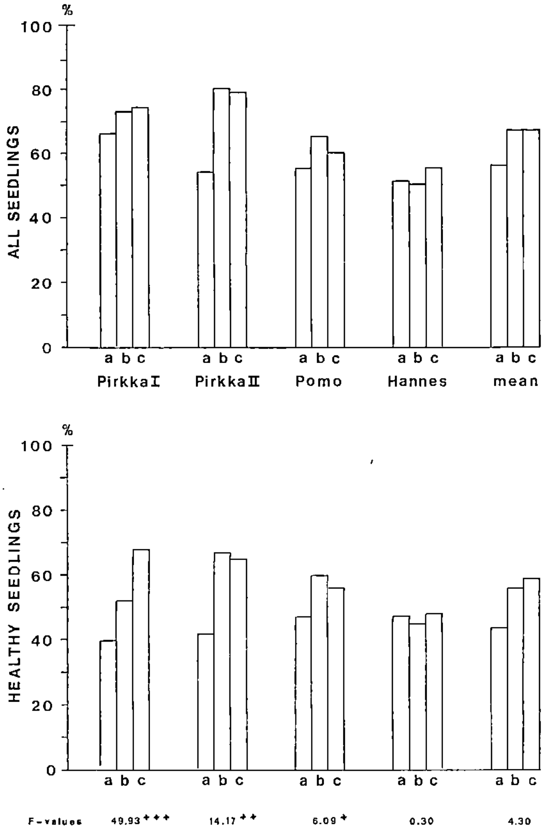

Fig. 1. Germination of seed lots with natural fusarial contamination. a = untreated, b = mercury, c = Bas 3302 F.

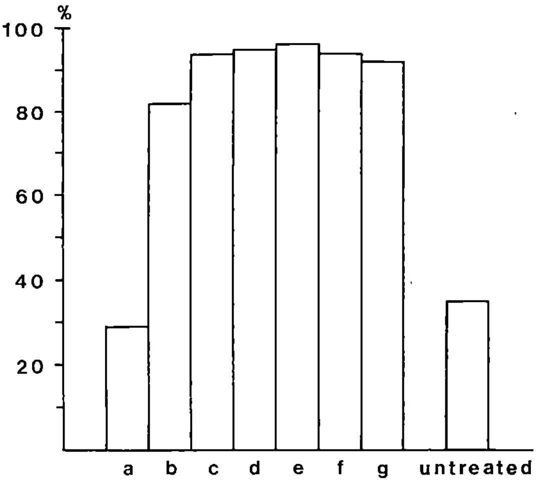

Fig. 2. Germination of artificially infected seeds treated with various fungicides (see Table 1. for the treatments).

also statistically significant (Fig. 1). Mercury and Bas 3 302 F appeared to be equal in efficacy, although the number of healthy seedlings was higher with the latter. The seed dressing in oats was less effective.

The artificially inoculated wheat in the greenhouse trial germinated very poorly without seed dressing. The percentage of sprouted seedlings was only 35 %. Germination was markedly improved with all chemical treatments, and, with most compounds, germination exceeded 90 % (Fig. 2). Carboxin used alone was the only ineffective treatment. Furthermore imazalil alone gave poorer results than carbendazim, imazalil + carbendazim or imazalil + carbendazim + carboxin.

In the 1977 field trial, both mercury and thiophanate-methyl treatment increased the number of seedlings, 16 % and 19 % respectively (Table 2). In 1978, the inoculation was clearly more damaging, because the non-inoculated seeds gave 189 % more seedlings, 52 % more seed heads and 45 % higher yield (Table 3). It is interesting to note that some chemical treatments gave higher yields than the non-inoculated control. The highest yield was given by mercury, although the seedlings percentage was best with *Trichoderma*-treatments and the number of seed heads was greatest with thiophanate-methyl.

Table 2. Field trial with artificial inoculation of *F. culmorum* in 1977.

Treatments	Number of seedlings per 24 row-metres	rf
Non-inoculated control ...	565	169
Inoculated control	338	=100
Mercury	385	116
Thiophanate-methyl	398	119
F-value	0.51	

Table 3. Field trial with artificial inoculation of *F. culmorum* in 1978.

Treatments	No. of seedlings		No. of heads		Yield	
	per 24 rm	rf	per 12 m^2	rf	kg/ha	rf
Non-inoculated control	704	289	364	152	1 989	145
Inoculated control	244	=100	240	=100	1 376	=100
Mercury	451	185	294	123	2 412	175
Thiophanate-methyl	488	200	412	172	2 186	159
9105/1	382	157	340	142	2 220	161
Trichoderma in seeds	457	187	319	133	2 006	146
Trichoderma in soil	461	189	352	147	1 921	140
F-value	0,23		0,43		0,80	

DISCUSSION

The beneficial effect of chemical seed dressing was rather modest in seed lots infected naturally with *Fusarium*. On the other hand, the occurrence of *F. culmorum*, which can be considered to be the most damaging species (Uoti 1976 a), was not very high compared to other *Fusarium* species. Similarly Bateman (1976) stated that the germination was clearly improved with seed treatments only when *F. culmorum* was the major species present. The slight superiority of systemic fungicides in contrast to mercury is, perhaps, explainable by refering to Colhoun (1972) who showed that the spores of *F. culmorum* also occur beneath the seed coat where disinfectant is not effective.

The growth of artificially inoculated seeds was greatly improved with the seed dressing in the greenhouse as well as in the field trials. In the greenhouse trial, it was found that the inefficiency of carboxin against *Fusarium* was similar to that shown by Massenot and Raynal (1972).

The results also indicated that the combination of imazalil and carbendazim may have a synergistic action against *Fusarium*. For the practical seed dressing an important finding was also that carboxin does not reduce the efficacy of the other two components of the tri-compound mixture.

In the case of artificial inoculation, the spores of *F. culmorum* naturally remain the seed surface. Therefore, it is obvious that mercury, which acts as a disinfectant, is quite effective. This was shown in the field trials, where there were no significant differences between the various treated and untreated trials. This is also, unfortunately, an important limitation when correlating the results from artificial inoculation with the practical field conditions.

The small size of the plots in the field trials limits the more reliable comparison of different treatments. Larger plots and the use of normal, mechanical equipment would give more uniform data (Clark 1977). However it was encouraging to note the good results with *Trichoderma*-seed treatment. Even more unexpected were the similarly good results with *Trichoderma*-soil treatment, despite the fact that there was no known soil infection by *F. culmorum*. *Trichoderma*-pelleting gave good control of soil infected by *F. culmorum* in the work of When-Shi Wu (1976). However, the practical utilization of *Trichoderma* or other antagonistic fungi needs more extensive studies, large scale production of spores, optimal concentration of spores in the treatment, storage and formulation problems being the most important targets.

Acknowledgements. — I wish to express my grateful thanks to Prof. Aarre Ylimäki and to the staff of Institute of Phytopathology of the Agricultural Research Centre, where the first part of this study was made. The latter part of the study, concerning artificial infection, was carried out in the research facilities of Kemira Oy.

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SELOSTUS

Siemensyntyisen Fusarium-saastunnan torjuntakokeita

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Luonnollisesti *Fusarium*-sienten saastuttamia ohra- ja kauraeriä peitattiin elohopeavalmisteella (Täyssato) ja elohopeattomalla koeaineella (Bas 3301 F) Maatalouden tutkimuskeskuksen kasvitautien tutkimuslaitoksessa. Astiakokeissa orastuvuus parani peittauksen ansiosta keskimäärin 56,5 %:sta 67,0 %:iin molemmilla valmisteilla. Vertailtaessa terveiden oraiden määrää elohopeaton peittausaine osoittautui paremmaksi. Sillä peitattujen erien orastuvuus oli 59,3 %. Elohopeapeittaus antoi orastuvuudeksi 56,0 % ja peittaamaton vain 44,0 %.

Kun terveitä kevätvehnän siemeniä saastutettiin patogeenisen *Fusarium culmorum*-sienen itiöillä, orastui siemenistä vain 35 % astiakokeissa. Peittaamalla saastutetut siemenet erilaisilla elohopeattomilla peittausaineilla ja aineseoksilla orastuvuus nousi parhaimmillaan 96 %:iin. Kokeillut aineet olivat karboksiini, karbendatsiimi ja imatsaliili yksinään ja erilaisina yhdistelminä. Ainoastaan karboksiini ja imatsaliili yksinään antoivat muita selvästi heikomman tuloksen.

Kenttäkokeissa v. 1977 ja 1978 samalla tavoin saastutettujen siementen orastuvuus parani v. 1977 elohopealla 16 % ja tiofanaattimetyylillä 19 %. Vuonna 1978 kaikki peittauskäsittelyt paransivat orastuvuutta, tähkien lukumäärää ja satoa varsin selvästi. Edellisten lisäksi kokeessa oli kolmoisseos, karboksiini + karbendatsiimi + imatsaliili. Valmisteiden välillä ei ollut merkitseviä eroja. Kemiallisten peittausaineiden kanssa yhtä hyvään tulokseen päästiin käsittelemällä saastutetut siemenet *Trichoderma*-sienen itiöillä tai kastelemalla maa saman sienen itiöliuoksella juuri ennen kylvöä.

ANNALES AGRICULTURAE FENNIAE, VOL. 18, 154—159 (1979)

Seria ANIMALIA NOCENTIA N. 104 — Sarja TUHOELÄIMET n:o 104

THE OCCURRENCE OF DIFFERENT PATHOTYPES OF THE POTATO CYST NEMATODE, GLOBODERA ROSTOCHIENSIS, IN FINLAND

MARJA LEENA MAGNUSSON

MAGNUSSON, M. L. 1979. **The occurrence of different pathotypes of the potato cyst nematode, Globodera rostochiensis, in Finland.** Ann. Agric. Fenn. 18: 154—159. (Agric. Res. Centre, Inst. of Pest Inv., SF-01300 Vantaa 30, Finland[1]).

The occurrence of different pathotypes of the potato cyst nematode, *Globodera rostochiensis* was studied in Finland. A random sample of 90 fields was taken from 700 known infestations. 84 populations were classified as a pathotype Ro 1, which therefore seems to be the dominant. The pathotype Ro 4 was found on four sites. Two of the studied populations did not fit into any pathotype group previously described.

This study indicates that resistant ex-*andigena* varieties can be generally recommended for use in plant rotation. However, as several pathotypes may occur simultaneously in the field populations, continuous growing of these varieties could increase resistance-breaking forms.

Index words: Nematoda, Heteroderidae, *Globodera pallida*, resistance.

INTRODUCTION

About 700 field infestations of the potato cyst nematode, *Globodera rostochiensis*, have been observed in Finland. These infestations occur mainly in the permanent potato growing areas in the southern and western parts of the country. New discoveries were also recently made in the important potato growing areas of Bothnia (SARAKOSKI 1976, 1977, SARAKOSKI & MUSTONEN 1978).

Since the discovery of nematode resistance in *Solanum vernei* and in some clones of *S. andigena* (ELLENBY 1948, 1952), both nematologists and plant breeders have been interested in using resistant potato varieties as a method of control against potato cyst nematodes. Giant cells, which are induced by females of these nematodes and which constitute their specific feeding sites, are usually not formed in the roots of resistant potatoes, and females fail to develop (PIEGAT & WILSKI 1963, TRUDGILL 1967). However, some females have been observed to complete their development on ex-*andigena* (HUIJSMAN 1956, TOXOPEUS 1956, WILLIAMS 1956), and resistance-breaking populations were found after continuous cultivation of these potatoes in Europe (JONES 1957, van der LAAN and HUIJSMAN 1957). As a result, several systems of identifying and classi-

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fying these new biotypes or pathotypes were developed, two of which, the British and Dutch schemes, were widely used in Europe (Kort 1974, Kort et al. 1977). The discovery of new sources of resistance led to the description of new pathotypes (Kort 1974), and as the classification of the different pathotypes was not uniform, identification was difficult. For that reason, two methods of classification and nomenclature of the pathotypes of potato cyst nematodes were established in 1977 (Canto Saenz and Mayer de Scurrah 1977, Kort et al. 1977).

Identification of the pathotypes is essential when resistant potatoes are recommended for their control. It is also necessary for a plant breeder to know which pathotypes are present in the country.

The purpose of this study is to give preliminary information about the occurrence and distribution of the pathotypes of the potato cyst nematode in Finland. The need for this study grew acute when the potato cyst nematode was found on large potato farms in the most important potato producing areas, and when the use of resistant ex-*andigena* varieties became more and more common.

MATERIAL AND METHODS

Soil samples, containing the potato cyst nematodes, were taken at random from infested potato fields in different parts of the country (Sarakoski 1976, 1977). Populations from northern Finland (province of Bothnia) were not included in the experiments due to low population densities. The sampling sites in the present investigation are shown in Fig. 1.

The tests to separate the populations, in which pathotype Ro 1 was dominant, were initially carried out by growing test plants in infested soil after estimating the initial population densities with Fenwick cans (Fenwick 1940). The test plants were *S. tuberosum* ssp. *andigena* var. Prevalent and *S. tuberosum* var. Veto. A method by which a fixed number of cysts were introduced into the test pots, was used later to separate the pathotype Ro 1 and to identify the resistance-breaking and doubtful strains. The cysts (25 or 50/pot) were enclosed in small nylon netting bags, but later, as the preparation of these bags proved to be laborious, the cysts (50/pot) were introduced directly into the pots. The number of replicates per plant was four. The test plants were grown in clean sand in the greenhouse. They were fertilized with a common potato fertilizer »Kloorivapaa Y». After a growth period of 3 months, the stems were cut, soil dried and the population densities estimated with Fenwick cans.

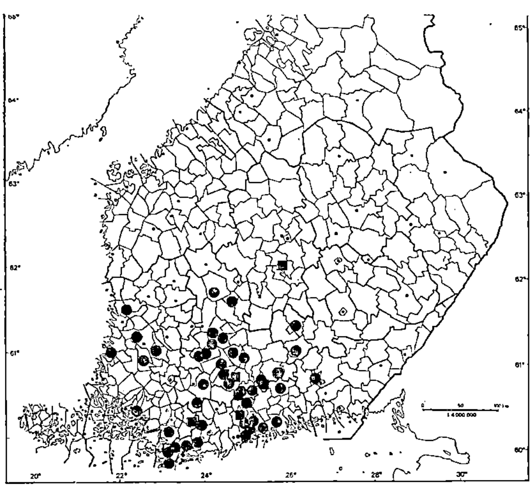

Fig. 1. Location of the studied populations. ● = Populations where the pathotype Ro 1 was dominant. ■ = Populations where resistance-breaking or doubtful strains were observed.

The test plants in the »resistance-breaking» tests were:

S. tuberosum var. Veto
S. tuberosum ssp. *andigena* var. Prevalent
S. kurtzianum hybr. KTT 60.21.19
S. vernei hybr. G.LKS 58.1642/4
S. vernei hybr. $(VT^n)^2$ 62.33.3
S. mutidissectum hybr. P 55/7

The results were calculated by using the ratio Pf/Pi (Pf = final population, Pi = initial population) (KORT et al. 1977). In this study, the ratio PfR/PfS (PfR = final population on resistant potatoes, PfS = final population on susceptible potatoes) was also used while calculating the results in the »Ro 1» tests in order to minimize the risk of errors due to low initial population densities. When cysts were introduced directly into the sand, 50 was subtracted from the number of cysts recovered at the end of the experiment to compensate for the initial population. The extraction efficiency of the Fenwick can is considered to be about 70 % (MAGNUSSON, M. L. unpubl. data). To compensate for this, the final numbers were divided by 0,70. As the extraction efficiency can be expected to be variable, 20 new cysts per pot was chosen as a limit for defining a population increase. Nomenclature proposed by KORT et al. (1977) is used in this study.

RESULTS

The experiments to separate pathotype Ro 1 from the other pathotypes were made with 90 populations. Both the ratio Pf/Pi and the ratio PfR/PfS were under 1,0 in the majority of the populations, which indicates the dominance of the pathotype Ro 1. The Pf/Pi and PfR/PfS ratios from the resistance-breaking and doubtful populations are given in Table 1. Fig. 1 shows the geographical distribution of populations dominated by pathotype Ro 1 and of the resistance-breaking and doubtful populations.

The results from the experiments to identify the resistance-breaking and doubtful populations are presented in Tables 2 and 3 and in Fig. 2. The ratio Pf/Pi shows that the pathotype Ro 1 is also dominant in many of these populations (Table 2). In certain cases the ratio Pf/Pi, which was calculated from the mean values of four replicates, was below 1,0 although reproduction was demonstrated in isolated replicates (Fig. 2).

Table 1. Pathotypic identification of resistance-breaking and doubtful populations. Innoculations on resistant ex-*andigena* and susceptible Veto potatoes. Pf (final) and Pi (initial) population on ex-*andigena*. PfR final population on ex-*andigena* and PfS final population on Veto.

Population	Pf/Pi	PfR/PfS
1. Hämeenlinna	0,1	2,0
2. Jyväskylä	0,4	1,4
3. Kangasala	0,04	0,1
4. Kärkölä	0,3	0,3
5. Lohja	0,1	0,7
6. Nurmijärvi	0,3	0,4
7. Perniö	0,2	0,6
8. Riihimäki	0,1	0,1
9. Ruovesi	0,7	0,5
10. Suomusjärvi	0,5	1,4
11. Säkylä	0,5	0,6
12. Turenki	0,2	0,6
13. Vantaa	0,02	0,5

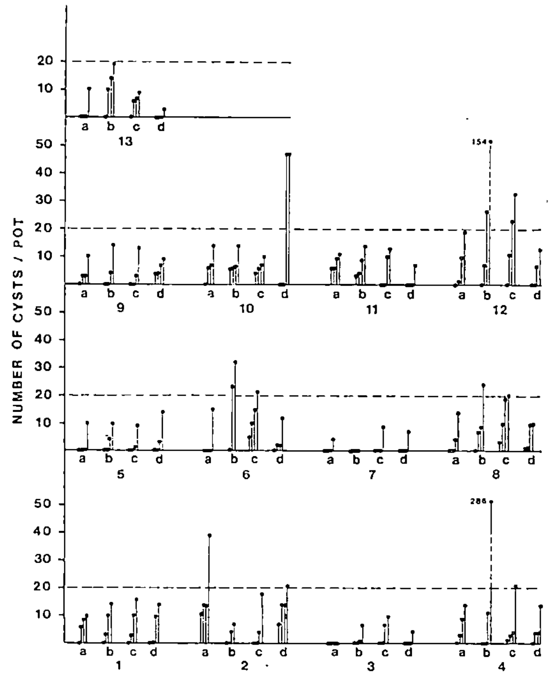

Fig. 2. Pathotypic identification of resistance-breaking and doubtful populations. The four replicates are illustrated individually on four test plants. Numbers are adjusted to compensate for 70 % extraction efficiency. Due to variation in the latter, the lower limit for a population increase was set at 20 cysts per pot. For the names of the populations see Table 1. Test plants: a = *S. tuberosum* spp. *andigena* var. Prevalent, b = *S. kurzianum* hybr. KTT 60.21.19, c = *S. vernei* hybr. G.LKS 58.1642/4 and d = *S. vernei* hybr. $(VT^n)^2$ 62.33.3.

Table 2. Pathotypic identification of resistance-breaking and doubtful populations on 6 internationally recommended test platns. Pf/Pi values are calculated from the mean values of four replicates. Pf (final population), Pi (initial population) (50 cysts/pot). For the names of the populations see table 1.

Test plants	1	2	3	4	5	6	7	8	9	10	11	12	13
S. tuberosum var. Veto	> 1	> 1	> 1	> 1	> 1	> 1	> 1	> 1	> 1	> 1	> 1	> 1	> 1
S. tuberosum ssp. *andigena* var. Prevalent	0,1	0,4	0	0,1	0	0	0	0	0,1	0,1	0,2	0,4	0
S. kurtzianum hybr. KTT 60.21.19	0,04	0	0	1,2	0	0,3	0	0,2	0,1	0,2	0,2	0,7	0,1
S. vernei hybr. G.LKS 58.1642/4	0,1	0,1	0,1	0,2	0	0,3	0	0,3	0	0,1	0	0,3	0,1
S. vernei hybr. $(VT^n)^2$ 62.33.3	0,02	0,3	0	0,1	0	0,1	0	0,1	0,1	0,4	0	0,1	0
S. multidissectum hybr. P 55/7	0,1	0,2	0	0,1	0,04	0,1	0	6,0	0	0,2	0,1	0	0,04

Table 3. Pathotypic identification of resistance-breaking and doubtful populations. Reproduction of the potato cyst nematodes on internationally recommended test plants. A summary of the information in table 2 and figure 2. Key: + = population increase on some or all replicates, — = no increase, ± = slight increase on some replicates. For the names of the populations see table 1.

Test plants	1	2	3	4	5	6	7	8	9	10	11	12	13
S. tuberosum var. Veto	+	+	+	+	+	+	+	+	+	+	+	+	+
S. tuberosum ssp. *andigena* var. Prevalent	—	+	—	—	—	—	—	—	—	—	—	—	—
S. kurtzianum hybr. KTT 60.21.19	—	—	—	+	—	+	—	±	—	—	—	+	—
S. vernei hybr. G.LKS 58.1642/4	—	—	—	±	—	±	—	—	—	—	—	+	—
S. vernei hybr. $(VT^n)^2$ 62.33.3	—	±	—	—	—	—	—	—	—	+	—	—	—
S. multidissectum hybr. P 55/7	—	—	—	—	—	—	—	+	—	—	—	—	—
Pathotype	Ro 1	?	Ro 1	Ro 4	Ro 1	Ro 4	Ro 1	Ro 1 Ro 4	Ro 1	?	Ro 1	Ro 4	Ro 1

Table 3 summarizes the results given in Table 2 and Fig. 2. The pathotype Ro 4 is dominant in the populations from Nurmijärvi (6), Turenki (12) and probably in the Kärkölä population (4). In the literature, populations capable of reproducing only on susceptible potatoes and *S. kurtzianum* hybr. KTT 60.21.19 have not been reported (Canto Saenz and Mayer de Scurrah 1977, Kort et al. 1977). In the present study, the Riihimäki population (8) reproduced only on these potatoes (Fig. 2), but, as some reproduction also appears to have taken place on *S. vernei* hydr. G.LKS 58.1 642/4, this population is probably not a new pathotype but rather an example of coexistence of the pathotypes Ro 1 and Ro 4. The populations from Jyväskylä (2) and Suomusjärvi (10) might, however, constitute new pathotypes; the first reproducing on the susceptible Veto, ex-*andigena* variety Prevalent and on *S. vernei* hydr. $(VT^n)^2$ 62.33.3, and the latter on Veto and *S. vernei* hybr. $(VT^n)^2$ 62.33.3 (Fig. 2). Further studies are necessary to verify these initial observations.

DISCUSSION

The investigation shows that the pathotype Ro 1 is dominant in the majority of the studied populations. Indeed, about 95 % of the populations were clearly dominated by this pathotype. As the populations were selected randomly, Ro 1 may be expected to dominate the majority of the Finnish potato cyst nematode populations. Therefore, growing of resistant ex-*andigena* potatoes might lead good pest control in the majority of the infested fields in Finland. However, as there can be several pathotypes in the field populations, the continuous growing of these varieties in infested fields might give rise to some aggressive pathotypes, and is therefore not recommended.

There are few localities where the dominant pathotype in the studied populations was other than Ro 1. The pathotype Ro 4 was discovered in Kärkölä, Nurmijärvi and Turenki. Nematodes belonging to this pathotype also seem to be present in the population at Riihimäki, although the pathotype Ro 1 obviously occurs simultaneously. It is, however, notable that growing the resistant ex-*andigena* varieties would lead to good pest control in these fields, because the nematodes in the pathotype Ro 4 do not reproduce on ex-*andigena* potatoes. As demonstrated above, Jyväskylä and Suomusjärvi populations do not belong to any of the described pathotypes. The Suomusjärvi population did not reproduce on ex-*andigena* potatoes, and this population could also be controlled with these varieties. The only population cabable of reproducing on ex-*andigena* was from Jyväskylä in central Finland.

Tables 2 and 3 show that all populations but one (Riihimäki) failed to reproduce on *S. multidissectum* hybr. P 55/7, which is resistant only against some pathotypes of the white potato cyst nematode, *G. pallida*. During this study, there have been difficulties in raising and storing this potato clone, and the seed potatoes have not been of high quality. Therefore, further work is necessary on *S. multidissectum*. A morphological study will be carried out on the resistance-breaking populations to investigate whether any of them belong to the species *G. pallida*. No observations of this nematode species have so far been made in Finland.

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SELOSTUS

Peruna-ankeroisen patotyypit Suomessa

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Peruna-ankeroisen biologisten rotujen eli patotyyppien esiintymistä ja yleisyyttä Suomessa alettiin tutkia peruna-ankeroisen levittyä omatarveviljelmien lisäksi suurille erikoistuneille perunaviljelmille, ja ankeroista kestävien nk. ex-*andigena*-perunoitten yleistyttyä. Näiden perunalajikkeitten ankeroisen kestävyys on peräisin *Solanum andigena*-lajista. Niiden juurissa eivät peruna-ankeroisnaaraat yleensä aikuistu, sillä juuriin ei tavallisesti muodostu naaraitten ravinnonotolle ja kehitykselle välttämättömiä jättiläissoluja. Peruna-ankeroisten tiedetään kuitenkin esiintyvän kymmenenä rotuna eli patotyyppinä, jotka on kuvattu sen perusteella, miten ne pystyvät lisääntymään eri villiperunalajikkeilla sekä *S. andigena*-risteymillä. Kaupan olevat resistentit ex-*andigena*-perunat kestävät vain kahta keltaisen peruna-ankeroisen, *Globodera rostochiensis*, patotyyppiä, patotyyppejä Ro 1 (ent. A) sekä Ro 4. Patotyyppien selvittäminen on tärkeää, kun ankeroista torjutaan kestävillä perunalajikkeilla.

Patotyyppitutkimus on nyt suoritettu 90 populaatiolla peruna-ankeroisen tärkeimmillä levinneisyysalueilla (kuva 1). Tutkimusta ei kuitenkaan ole vielä voitu suorittaa Pohjanmaan ankeroisilla, sillä saastunnat ovat siellä niin lieviä, ettei ankeroisten määrä ole riittänyt kokeisiin. Tutkimukset osoittivat, että patotyyppiin Ro 1 voidaan laskea kuuluviksi kaikkiaan 84 tutkituista populaatioista eli n. 95 %, eikä mikään osoita, etteikö suunnilleen näin suuri osuus kaikista Suomen peruna-ankeroispopulaatioista kuuluisi tähän patotyyppiin. Patotyyppiin Ro 4 kuuluvia ankeroisia löydettiin Kärkölästä, Nurmijärveltä ja Turengista, ja tähän patotyyppiin kuuluvia ankeroisia näyttää olevan myös Riihimäen populaatiossa patotyypin Ro 1 rinnalla. Jyväskylän ja Suomusjärven populaatiot eivät sopineet mihinkään aikaisemmin kuvattuun patotyyppiin (Canto Saenz ja Mayer de Scurrah 1977, Kort ym. 1977). Yksityiskohtaiset tutkimukset näillä populaatioilla ovat paikallaan.

Yhteistä kaikille tutkituille populaatioille Jyväskylän populaatiota lukuunottamatta on se, että ne eivät lisäänny ex-*andigena*-perunoilla eli yleisesti käytössä olevilla ankeroista kestävillä perunalajikkeilla. Tällöin voidaankin hyvällä syyllä olettaa, että suurimmassa osassa maata saadaan hyviä tuloksia peruna-ankeroisten torjunnassa näitä lajikkeita viljelemällä. On kuitenkin muistettava, että todennäköisesti useimmissa peruna-ankeroispopulaatioissa on vallitsevan patotyypin rinnalla muita, jotka tulevat yleensä esiin vasta, kun resistenttejä perunoita on viljelty vuodesta toiseen. Useissa maissa saadut kokemukset osoittavatkin, että resistenteillä perunoilla saadaan parhaat tulokset ankeroisten torjunnassa, kun niitä viljellään saastuneessa pellossa vain joka toinen tai kolmas vuosi.

Tutkimuksessa käytetyt *S. mulitidissectum*-villiperunalajikkeen siemenperunat ovat olleet huonoja, eikä taulukoissa 2 ja 3 saatuihin tuloksiin voi varauksetta luottaa. Tämä villiperunahybridi on osoittautunut kestävän vain eräitä valkoisen peruna-ankeroisen, *G. pallida*, patotyyppejä. Siksi voidaankin vasta parhaillaan suoritettavan morfologisen tutkimuksen perusteella sanoa varmuudella, kuuluuko jokin tutkimuksessa havaituista patotyyppinsä suhteen epäselvistä populaatioista *G. pallida*-lajiin.

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IRRIGATION REQUIREMENTS OF THE STRAWBERRY

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Irrigation experiments with the strawberry were carried out at the Horticultural Research Institute, Piikkiö, in 1976—1978, using 0, 10, 20 and 30 mm of water and three different irrigation times: irrigation in early summer until the end of flowering; irrigation during the development phase of the unripe fruit; and irrigation during the differentiation phase of the buds.

Heavy irrigation from early summer up to harvesting raised the year's yield by increasing the mean berry size. Irrigation during development of the unripe fruit, followed by a dry period, increased the following year's yield through an increase in the number of fruit. Irrigation in August, after the harvest, reduced the following year's yield by hampering differentiation of the buds.

Index words: Strawberry, irrigation.

INTRODUCTION

Water requirements of the strawberry fluctuate greatly between different stages of the plant's development. Depending on the timing of artificial irrigation, this can either lead to an increased yield or be detrimental in its effects.

In his 1955 experiments incorporating 5 × 30 mm irrigation, THORSRUD (1958) obtained a 39,2 % increase in yield. There was a 26,5 % increase in berry size, but it was observed that irrigation delayed the harvest during both the current and the following seasons. The delay in the current season's harvest was due to premature ripening in dry replications, while that of the following season was probably caused by the differentiation of the buds being delayed by autumn irrigation.

In experiments carried out in Alnarp and Nyckelby, applications of 10—35 mm of water were made each time. The experiments indicated a significant improvement with irrigation, both in the quality and quantity of the yield. The overall increase in yield obtained in Alnarp was 40 %, and that in Nyckelby 100 %. Both berry size and the number of berries increased as a result of the watering. The harvest was not significantly delayed, but irrigation lengthened the harvesting period by 1—2 days. The yield was also higher from the first harvest in the non-irrigated control (Bjurman 1974).

In order to determine the most favourable time for irrigation, pot treatments have also been carried out in Germany with the Senga Sengana variety under glasshouse conditions. The development of runners progressed better the earlier the irrigation was applied, though the largest growth of runners was obtained from the continuously damp treatment. The yield in the continuously damp treatment with 1-year-old plants was 50 % higher and with 2-year-old plants 30 % higher than in the continuously dry control.

Heavy irrigation before and during the early stage of flowering increased the subsequent yield by leading to an increase in the number of fruit; irrigation at the height of flowering, and during the harvest, did so by increasing the weight of the fruit. If irrigation was not commenced until the harvest time had already been reached, no effect was obtained. Irrigation at the end of September encouraged the differentiation of the flower buds on the plants, and led to a 20 % increase in the number of fruit the following year; but irrigation in August was clearly detrimental in its effects (Naumann 1961).

Since it is precisely the differentiation of the flower buds which determines the most favourable timing for irrigation of the strawberry, Naumann (1964) concentrated on investigating this in his later experiments.

Heavy irrigation prior to the initiation of the flower buds by light conditions also deterred differentiation, and thus reduced the number of flowers the following year; this occurred with the plants watered in August and to some extent in September. However in those plants where differentiation of the flower buds had already occurred, a high moisture level in the soil encouraged their development, increasing the number of both flowers and fruit the following year; this occurred with some of the plants watered in September and all of those watered in October.

Irrigation in May and even in June leads to a radical increase in flowers and fruit in the same season, due to the continued development of the flower buds, the differentiation of which had begun the previous autumn. In comparison with the controls, the number of fruit the following year was increased 13 % by April irrigation, 15 % by irrigation in September, and 36 % by irrigation in October, but was reduced 12 % by irrigation in June and 25 % by irrigation in August (Naumann 1964).

In field experiments in Norway, Kongsrud (1970) investigated the question from a different angle by studying the effect of a dry period at different stages of the strawberry's development. The number of flower stems per plant was greatest when the plants were exposed to a dry period in August after the harvest and were heavily watered in September. These plants gave the biggest yield the following year. The berry yield was most reduced when the dry period occurred immediately before or during the harvest time. The observations made in the third year showed that a dry period in August—September led to early ripening the following year.

The production of runners suffered most from a dry period at the beginning of the season, and least from one in September. When the experiment was discontinued, the largest plants were those in the treatment which was dry in August, i.e. immediately following the harvest (Kongsrud 1970).

The quantity and timing of irrigation were also investigated in an experiment carried out on the strawberry at the Horticultural Research Institute in Piikkiö starting in 1975, the results of which are set out below.

MATERIAL AND METHODS

The experiment were set up in two contrasted types of soil; coarser fine sand, and sandy clay. The soil properties of the different soils, and their water retention characteristics are given in Table 1.

Table 1. Mechanical analysis and composition by soil properties; sandy and clay soils.

	Grain diameter, mm							Volume weight	Field capacity	Wilting point	Available water capacity
	Coarser sand 2—0,6 %	Sand 0,6—0,2 %	Fine sand 0,2—0,06 %	Finer finesand 0,06—0,02 %	Coarser silt 0,02—0,006 %	Finer silt 0,006—0,002 %	Clay 0,002 %	kg/l	%	%	%
Clay soil	0,9	3,5	23,8	9,4	11,7	11,0	39,7	1,12	35,1	17,3	17,8
Sandy soil		14,0	72,1	3,5	2,2	1,5	5,7	1,2	17,9	7,4	10,5

The variety used in the experiments was Senga Sengana. The plants were bedded on 3 June 1975 at a planting distance of 1 × 0,33 m. The size of each irrigation replication was 3 × 4 m, containing 36 plants. In the planting year, all of the plants were fertilized and watered in the same way to ensure good initial growth. The experimental treatment was started in 1976, the first year to yield a crop.

The soil moisture was monitored at a depth of 10 cm with plaster blocks, using J. D. Frost's meter. Measurements were taken daily. The irrigation limit in the experiments was 50 % available water in the soil. The replications which were to be kept dry were covered with plastic shades during irrigation.

The quantities of water applied in the irrigation quantity experiment were 0, 10, 20, and 30 mm of water at a single application. The timing of irrigation was determined by reference to the 20 mm treatment, which was not allowed to fall below the irrigation limit throughout the growth season. All the treatments were equally exposed to natural rainfall. Each replication in the experiment contained two levels of fertilization; half of the replication received 300 kg/ha of garden fertilizer (11—11—22) received 600 kg/ha.

In the irrigation timing experiment, irrigation was carried out at the following phases:

- in early summer until the end of flowering;
- during the development phase of the unripe fruit;
- during the differentiation of the flower buds.

Irrigation was applied by sprinkler as soon as the moisture level in the treatment next due for watering had fallen below the irrigation limit.

RESULTS AND DISCUSSION

The 1976 season was unusually dry. The soil moisture at a depth of 10 cm in the unwatered control in sandy and clay soils, and the precipitation per 10-day period, are shown in Fig. 1. This shows that the clay soil dried out to the irrigation limit a month before the sandy soil. The clay soil had to be watered for the first time at the end of May/beginning of June, but the sandy soil did not need watering until the beginning of July, when the strawberries were already bearing unripe fruit. During the flowering period, the sandy soil never dried out below the irrigation limit. The reason for the maintenance of soil moisture in the sandy clay is probably upward water seepage by capillary action.

The quantities of water applied to each treatment are given in Table 2. Since irrigation on the sandy soil was not started until later in the season, it no longer had any effect on the same year's yield, whereas on the clay soil, the effect of irrigation on yield was already clearly

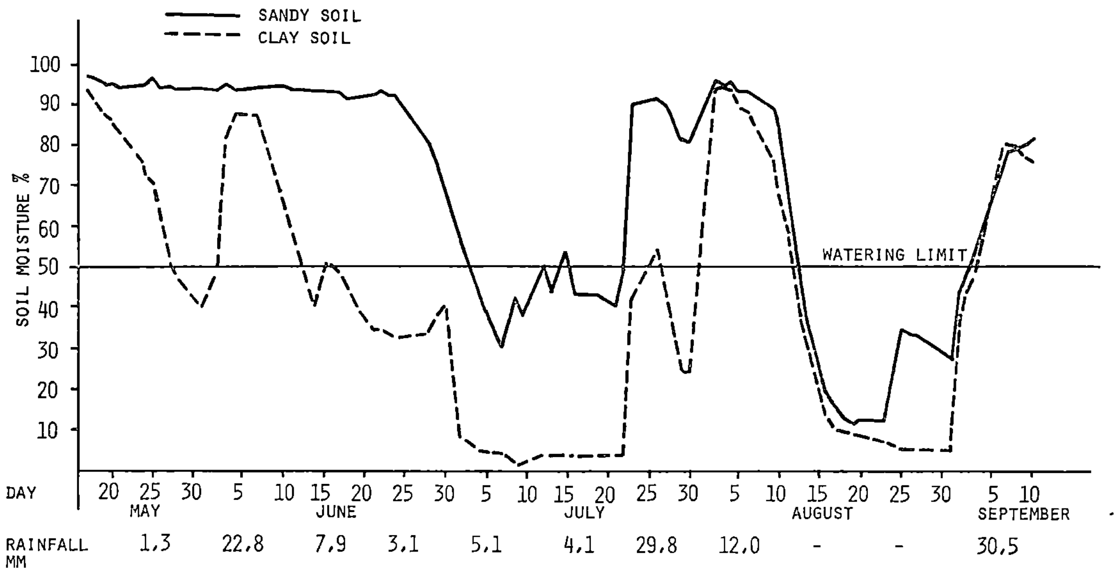

Fig. 1. The percentage soil moisture of the available water capacity at a depth of 10 cm, and the rainfall in 10-day periods during 1976.

Table 2. Irrigation quantity experiment. Quantities of water applied in 1976/1977, by treatments.

Treatment	Total irrigation in mm			
	Sandy soil		Clay soil	
	1976	1977	1976	1977
Unwatered	0	0	0	0
10 mm water	30	10	70	40
20 mm water	60	20	140	80
30 mm water	90	30	210	120

observable in the first year. The total yield, divided into marketable, small-sized, and rotted fruit, is given in Table 3.

On the clay soil, the yield obtained with maximum irrigation showed an increase of 19 % against the unwatered control. Irrigation led to a lower percentage of small-sized fruit, but the proportion of rotted fruit rose correspondingly, so that the proportion of marketable fruit in each treatment remained approximately the same, though this meant an increase in absolute weight. The increased yield was mainly due to increased berry size. The mean berry size is given in Table 4.

Irrigation also delayed the harvest: in the unwatered control on clay soil, 64 % of the total yield was harvested during the first two weeks of harvesting, as against 52 % in the maximum-irrigation treatment. The corresponding figures for sandy soil show a similar trend. Irrigation increased the yield of runners on both soils, though to a greater extent on the clay soil; the number of runners per plant in the unwatered control was 13,1 per plant, while in the maximum-irrigation treatment it was 29,9 per plant.

The quantities of water applied to each treatment in the timing experiment are given in Table 5. The impact of the irrigation on the first harvest was very small, with the final irrigation, moreover, occurring after the actual harvest. However irrigation during the ripening of the fruit can be seen to have increased both the berry weight and the proportion of rotted fruit in this experiment.

The rainfall in the following season, 1977, was considerably heavier than in the preceding year. In the sandy soil, the soil moisture never once fell below the irrigation limit, so that the only irrigation effect traceable in this yield is that of the previous year's irrigation. The soil moisture in the unwatered controls for both soils, and the precipitation for each 10-day period in 1977 are presented in Fig. 2.

In contrast, the clay soil did need watering in that year, especially during June. The findings

Table 3. Irrigation quantity experiment. Total yield and composition, 1976.

Treatment	Sandy soil				Clay soil			
	Total yield kg/100 m²	Percentage composition			Total yield kg/100 m²	Percentage composition		
		Market-able	Small-sized	Rotted		Market-able	Small-sized	Rotted
Unwatered:								
Garden fertilizer (11-11-22)								
300 kg/ha	103	91	6	3	67	86	10	4
600 kg/ha	110	91	6	3	72	85	9	6
10 mm water:								
Garden fertilizer								
300 kg/ha	103	92	6	2	66	85	7	8
600 kg/ha	100	90	7	3	81	82	6	12
20 mm water:								
Garden fertilizer								
300 kg/ha	110	91	6	3	69	84	5	11
600 kg/ha	109	89	5	6	80	83	6	11
30 mm water:								
Garden fertilizer								
300 kg/ha	106	92	5	3	86	85	3	12
600 kg/ha	103	91	5	4	79	83	4	13

Table 4. Irrigation quantity experiment. Berry weight and the proportion of the total yield harvested during the first two weeks, 1976.

Treatment	Sandy soil		Clay soil	
	Berry weight g	1st 2 wks' harvest %	Berry weight g	1st 2 wks' harvest %
Unwatered:				
Garden fertilizer (11-11-22)				
300 kg/ha	9,3	68	7,4	62
600 kg/ha	8,9	65	7,6	65
10 mm water:				
Garden fertilizer				
300 kg/ha	9,2	63	8,0	60
600 kg/ha	8,6	68	8,6	60
20 mm water:				
Garden fertilizer				
300 kg/ha	9,6	60	8,8	57
600 kg/ha	9,4	58	8,6	57
30 mm water:				
Garden fertilizer				
300 kg/ha	9,3	64	9,6	51
600 kg/ha	9,6	62	9,4	53

for clay soil thus reflect both the previous year's and the current year's irrigation. The effect in the second year of the timing of irrigation both on the total crop, and its composition in terms of marketable, small-sized, and rotted fruit is presented in Table 6.

The good water economy of the sandy soil is indicated by the fact that, irrespective of timing, irrigation did not bring about an increase in yield in comparison with the unwatered control. On the other hand, irrigation after the harvest, during differentiation of the flower buds, led to a notable reduction in the total yield. On the clay soil, the best results were obtained with irrigation during the ripening of the fruit. No increase in yield was obtained with irrigation during the period of differentiation of the flower buds, despite the harsh drought in the preceding August. The differences in yield are not due to berry size (Table 7), but to the number of berries. Moisture in August hampered the differentiation of the

Table 5. Irrigation timing experiments. Quantities of water applied in 1976/1977, by treatments.

Treatment	Total irrigation in mm			
	Sandy soil		Clay soil	
	1976	1977	1976	1977
Unwatered	0	0	0	0
Irrigation in early summer until the end of flowering	0	0	60	60
Irrigation during ripening of the fruit	40	0	80	20
Irrigation during flower bud differentiation	40	0	40	20

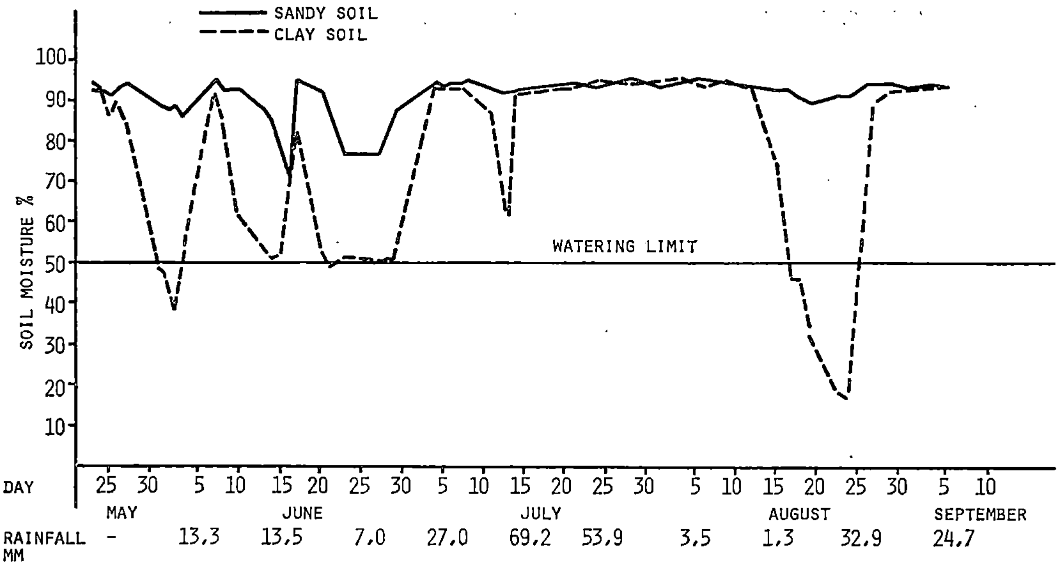

Fig. 2. The percentage soil moisture of the available water capacity at a depth of 10 cm, and the rainfall in 10-day periods during 1977.

Table 6. Irrigation timing experiments. Total volume and composition of yield, 1977.

Treatment	Sandy soil				Clay soil			
	Total yield kg/100 m²	Composition			Total yield kg/100 m²	Composition		
		Marketable %	Small-sized %	Rotted %		Marketable %	Small-sized %	Rotted %
Unwatered	119	66	2	32	143	66	3	31
Irrigation in early summer until the end of flowering	117	66	2	32	143	67	2	31
Irrigation during ripening	117	70	2	28	148	67	2	31
Irrigation in late summer, during flower bud differentiation	107	65	2	33	143	67	2	31

Table 7. Irrigation timing experiments. Berry weight and the proportion of the total yield harvested during the first two weeks, 1977.

Treatment	Sandy soil		Clay soil	
	Berry weight g	1st 2 wks' harvest %	Berry weight g	1 st 2 wks' harvest %
Unwatered Control	9,6	40	9,4	53
Irrigation in early summer until the end of flowering	9,7	40	9,6	47
Irrigation during the ripening of the fruit	9,6	45	9,1	56
Irrigation in late summer during flower bud differentiation	9,9	35	10,3	43

flower buds are reduced their numbers. The earliness of the harvest is indicated by the proportion of the total yield harvested during the first two weeks (Table 7).

Differentiation of the flower buds was advanced by irrigation during the ripening of the fruit, followed by a dry period. The buds were thus further advanced the following spring, which led to an earlier harvest on both soils. On the other hand, irrigation after the harvest hampered differentiation of the flower buds, and thus delayed the following year's harvest.

The findings from the irrigation quantity experiments in 1977 reinforced the findings

Table 8. Irrigation quantity experiment. Total yield and composition, 1977.

Treatment	Sandy soil				Clay soil			
	Total yield kg/100 m²	Percentage composition			Total yield kg/100 m²	Percentage composition		
		Marketable %	Small-sized %	Rotted %		Marketable %	Small-sized %	Rotted %
Unwatered:								
Garden fertilizer (11-11-22)								
300 kg/ha	112	66	2	32	123	71	1	28
600 kg/ha	102	59	2	39	113	64	1	35
10 mm water:								
Garden fertilizer								
300 kg/ha	123	68	1	31	131	76	1	23
600 kg/ha	101	59	1	40	117	64	1	35
20 mm water:								
Garden fertilizer								
300 kg/ha	95	63	1	36	127	73	1	26
600 kg/ha	88	58	2	40	122	73	1	26
30 mm water:								
Garden fertilizer								
300 kg/ha	97	62	1	37	133	75	2	23
600 kg/ha	90	61	2	37	131	69	1	30

from the irrigation timing experiments, and confirmed the detrimental effects of irrigation in August. This was particularly clear on the sandy soil, where the larger the quantity of water applied in the preceding August, the smaller the yield the following year. The potential benefit from the current year's irrigation was also cancelled out on the clay soil, by the detrimental effects of irrigation during the preceding autumn. The total yields, and their composition in terms of marketable, small-sized, and blighted berries are given in Table 8. Irrigation did not lead to increased benefit being derived from fertilization; on the sandy soil a better yield was obtained from the treatment with the lower level of fertilization; on the clay soil, the results are not so marked. On both soils, heavier fertilization led to a higher proportion of blighted fruit.

The evidence presented permits the following recommendations for the strawberry: generous irrigation during the early summer and especially during the ripening of the fruit. However, in the irrigation of the strawberry special attention must often be given to grey mould *(Botrytis cinerea)* prevention, since the disease spreads rapidly on wet vegetation. In August, following the harvest, a dry period appears to be favourable to differentiation of the flower buds. In the autumn, under Finnish conditions, natural moisture is normally sufficient.

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Maatalouden tutkimuskeskus

Puutarhantutkimuslaitoksessa Piikkiössä käytettiin mansikalla kastelukokeissa 1976—78 kastelumääriä 0—30 mm kerralla ja kolmea erilaista kasteluajankohtaa, jotka olivat kastelu kevätkesällä kukinnan loppuun asti, kastelu raakileiden kehittymisvaiheessa ja kastelu sadonkorjuun jälkeen kukkasilmujen erilaistumisvaiheessa. Kasvukausi 1976 oli poikkeuksellisen kuiva, mutta seuraavien vuosien, 1977 ja —78, runsaat sateet pitivät maan kosteuden kenttäkapasiteetissa kyseisten kasvukausien aikana lähes jatkuvasti.

Kastelu kevätkesällä aina sadonkorjuun alkuun asti nosti saman vuoden satoa kohottamalla marjan keskipainoa. Kastelu raakileiden kehittymisvaiheessa nosti myös seuraavan vuoden satoa lisäämällä marjojen lukumäärää. Kastelu sadonkorjuun jälkeen vähensi ja viivästi seuraavan vuoden satoa ehkäisemällä kukkasilmujen erilaistumista. Kastelu ei näyttänyt lisäävän lannoitteiden hyväksikäyttöä marjasadon kannalta, rönsysato sen sijaan suureni lannoitustason noustessa.

ANNALES AGRICULTURAE FENNIAE, VOL. 18: 168—170 (1979)

Seria ANIMALIA NOCENTIA N. 105 — Sarja TUHOELÄIMET n:o 105

RESEARCH NOTE

HARMFULNESS OF SOIL TREATMENT WITH SOME FUNGICIDES AND INSECTICIDES TO THE BIOLOGICAL CONTROL AGENT APHIDOLETES APHIDIMYZA (ROND.) (DIPT., CECIDOMYIIDAE)

MARTTI MARKKULA, MAIJA RIMPILÄINEN and KATRI TIITTANEN

MARKKULA, M., RIMPILÄINEN, M. & TIITTANEN, K. 1979. **Harmfulness of soil treatment with some fungicides and insecticides to the biological control agent Aphidoletes aphidimyza (Rond.) (Dipt., Cecidomyiidae).** Ann. Agric. Fenn. 18: 168—170. (Agric. Res. Centre, Inst. Pest Inv., SF-01300 Vantaa 30, Finland.)

Soil disinfection against pathogenic fungi by benomyl and thiram is possible concurrently with biological control of aphids by *Aphidoletes aphidimyza* (Rond.). These fungicides do not reduce the emergence of adults from pupae in the soil. Diazinon, malathion, mevinphos and pyrethrin are harmful to *A. aphidimyza* so they cannot be used in soil treatment against pests.

Index words: *Aphidoletes aphidimyza*, adult emergence, soil treatment, benomyl, thiram, diazinon, malathion, mevinphos, pyrethrin.

Methods for mass-rearing and using the aphid midge *Aphidoletes aphidimyza* (Rond.) in biological control of aphids in glasshouses have been developed in Finland (e.g. MARKKULA and TIITTANEN 1977). In 1978 the use of *A. aphidimyza* was started on commercial vegetable cultures with good results (MARKKULA 1978, RIMPILÄINEN 1978).

Because it is necessary to use chemicals concurrently with biological control especially against fungi and pests living in the soil, it was considered necessary to investigate the harmfulness of the most commonly used fungicides and insecticides used in soil treatment to the pupae (cocoons) of *A. aphidimyza* and adults emerging from the pupae.

An attempt was made to find out if these fungicides and insecticides could be used in glasshouses in which aphids are controlled biologically by *A. aphidimyza* and in which the soil contains variable amounts of *A. aphidimyza* pupae.

There are some studies on the effects of insecticides, acaricides and fungicides on eggs, larvae and adults of *A. aphidimyza* (see e.g. USHEKOV 1975, SELL 1975, MARKKULA and TIITTANEN 1976, ADAMS and PROCOPY 1977). Insecticides have generally been harmful but acaricides and fungicides harmless to *A. aphidimyza*. Previously there have been no studies on the effect of chemicals used in soil disinfection on the adult emergence of *A. aphidimyza* from pupae.

The ability of chemicals to kill pupae and newly emerged adults of *A. aphidimyza* was investigated in the laboratory in the summer 1978. The temperature in the laboratory varied from 20 to 24°C and the relative humidity from 40 to 60 %. During the experiments the larvae were fed with green peach aphids (*Myzus persicae* Sulz.) on capsicums (*Capsicum annuum* L.). Third instar larvae on capsicum leaves were put in special jars for pupation (see MARKKULA and TIITTANEN 1977), 100 larvae in each. There were two replicates of each test unit, 200 larvae altogether. Fine peat, the kind used as growth substrate in glasshouses, was used as pupation substrate.

The peat was treated with chemicals 5—6 days after the larvae had disappeared in the peat. The effect of the chemicals was determined by the amount of the migdes emerging in each test unit and by the adult survival rate. The emergence was checked daily. The midges that lived at least 2 days were considered surviving.

The chemicals were used in concentrations that usually are recommended for controlling fungi and pests living in soil on glasshouse cultures. One litre of diluted fluid chemicals and 20 g/m² of granular diazinon was used. The concentrations were as follows:

Fungicides:
50 % benomyl, Benlate 0,15 %
80 % thiram, Pomarsol forte 1,5 %

Insecticides:
10 % diazinon, Basudin 10
50 % malathion, Malan 0,2 %
24 % mevinphos, Fosdrin 0,05 %
6,25 % pyrethrin, Pyretriini-yleisruiskute 0,1 %

The following results were obtained from the different treatments:

	adults emerged	adults survived
benomyl	175	173
thiram	158	153
diazinon	0	0
malathion	34	0
mevinphos	104	36
pyrethrin	34	34
untreated	178	178

The treatment of the pupation substrate with benomyl and thiram did not diminish the adult emergence neither did it shorten the life time of the adults. The insecticides diazinon and malathion destroyed all pupae or at least the adults that had emerged before they got to the surface of the peat. Mevinphos and pyrethrin had also a harmful effect even if a small part of the adults emerged from the pupae and some of them even survived.

The results indicate that soil can be disinfected with benomyl and thiram without disturbing a concurrent biological control of aphids. On the contrary diazinon, malathion, mevinphos and pyrethrin destroy the migdes and these chemicals cannot be used when aphids are controlled biologically by *A. aphidimyza*.

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SELOSTUS

Maan käsittelyyn käytettävien torjunta-aineiden haitallisuus uudelle torjuntaeliölle, kirvasääskelle

Martti Markkula, Maija Rimpiläinen ja Katri Tiittanen

Maatalouden tutkimuskeskus, tuhoeläinosasto

Kun kasvihuoneviljelyksillä torjutaan lehtikirvoja biologisesti uuden torjuntaeliön, kirvasääsken (*Aphidoletes aphidimyza*) avulla, joudutaan usein samanaikaisesti käyttämään maan desinfiointiaineita kasvitautien torjumiseksi ja tuhoeläinten torjunta-aineita maassa elävien tuhoeläinten torjumiseksi

Kokeet osoittivat, että benomyyli ja tirami eivät tapa maassa eläviä kirvasääsken koteloita. Näitä aineita voidaan siis käyttää maan desinfiointiin silloinkin, kun kasvihuoneisiin on levitetty kirvasääskeä lehtikirvojen torjumiseksi.

Tuhoeläinten torjunta-aineet diatsinoni, malationi, mevinfossi ja pyretriini ovat kokeiden mukaan haitallisia kirvasääskelle. Jos niitä käytetään maassa elävien tuhoeläinten vahinkojen ehkäisemiseen, häiriintyy lehtikirvojen biologinen torjunta.

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Seria ANIMALIA NOCENTIA N. 106 — Sarja TUHOELÄIMET n:o 106

RESEARCH NOTE

SUITABILITY OF VARIOUS MATERIALS FOR THE PUPATION SUBSTRATE OF APHIDOLETES APHIDIMYZA (ROND.) (DIPT., CECIDOMYIIDAE)

MARTTI MARKKULA, MAIJA RIMPILÄINEN and KATRI TIITTANEN

MARKKULA, M., RIMPILÄINEN, M. & TIITTANEN, K. 1979. **Suitability of various materials for the pupation substrate of Aphidoletes aphidimyza (Rond.) (Dipt., Cecidomyiidae) adults.** Ann. Agric. Fenn. 18: 171—173. (Agric. Res. Centre, Inst. Pest Inv., SF-01300 Vantaa 30, Finland.)

The effect of pupation substrate on the adult emergence and the length of pupal period of *Aphidoletes aphidimyza* (Rond.) was investigated. Sand, peat, vermiculite, perlite, rockwool and mixtures of vermiculite and sand, vermiculite and peat, perlite and sand, perlite and peat were used as pupation substrates. Only in perlite was the adult emergence clearly less than in the other pupation substrates. None of the substrates had a significant effect on the length of pupal period. The lightest pupation substrate was peat. On the basis of the results peat is being used as a pupation substrate in the mass-production of *A. aphidimyza*.

Index words: *Aphidoletes aphidimyza*, Cecidomyiidae, pupation substrate, sand, peat, vermiculite, perlite, rockwool, adult emergence, length of pupal period.

A mixture of sand and peat (UYGUN 1970) and sand (BONDARENKO and ASYAKIN 1975, MARKKULA and TIITTANEN 1977) has been used as a pupation substrate in mass-rearings of the aphid midge *Aphidoletes aphidimyza* (Rond.). Pupae of the aphid midge became available for commercial growers in Finland in the spring 1978. They were supplied in their pupation substrate, in humid sand, which turned out to be too heavy a pupation substrate raising the postage. That was why a decision was made to investigate the applying of lighter materials as pupation substrate in which the pupae are delivered to the growers.

The experiments were done in the summer 1978 in the laboratory. The temperature varied from 20 to 24°C and the relative humidity from 40 to 50 %. A 3,5 cm layer of sand was put at the bottom of the jars used in the experiments, a nylon gauze was placed of the sand and on top of it a 1 cm layer of the substrate studied. This upper layer with the pupae is sent to growers in plastic containers.

The larvae were fed with green peach aphids (*Myzus persicae* Sulz.). Each test unit consisted of two jars with 100 larvae in each. The adult emergence and the developmental period of pupae were figured out. The substrates were kept humid and they were weighed after the emerging of adults had finished. The mixed substrates were made 1: 1.

The nine substrates studied were:

Sand-control	Sand + peat
Peat	Vermiculite + sand
Perlite	Vermiculite + peat
Vermiculite	Perlite + sand
Rockwool	Perlite + peat

The adult emergence remained lower than normal in all pupation substrates. Even in sand it was only 45 % although it has usually varied from 70 to 80 %. The reason for the low adult emergence is unexplained. Possibly it was caused by a temporary drying of the pupation substrate. The adult emergence was about the same in all substrates but not in perlite in which only 20 % of the larvae became adults. The primary reason for this was the fact that the wings of the emerging adults were glued in the perlite granules. Mixing peat or sand with perlite removes this harm.

The experiment indicated that *A. aphidimyza* is able to pupate in rockwool and that the adults are able to emerge from it. Rockwool is used as growth substrate to some extent in glasshouses.

Table 1. Effect of pupation substrate on the emergence of *Aphidoletes aphidimyza* adults.

	Weight g/0,25 l	Number of adults emerging	%	Time of pupal development
Peat	130	117	58	10
Vermiculite	186	112	56	11
Perlite	153	40	20	11
Rockwool	218	79	40	11
Sand + peat 1 : 1	267	78	38	10
Vermiculite + sand 1 : 1	339	105	53	11
Vermiculite + peat 1 : 1	169	110	55	11
Perlite + sand 1 : 1	351	78	39	11
Perlite + peat 1 : 1	165	104	52	11
Control, sand a	436	104	52	11
Control, sand b	440	96	48	11
Control, sand c	512	68	34	11

The pupation substrate did not have any significant effect on the developmental period of pupae (Table 1).

The adult emergence was high in peat. About 80 % of the pupae have turned adults in the spring and in the summer and 60 % in the fall and in the winter when using peat as a pupation substrate in mass-rearing of the midge in practice. As peat was the lightest of the substrates investigated, it has been used as a pupation substrate in the mass-rearing of *A. aphidimyza*. The light weight of peat is an advantage when supplying the growers pupae in their pupation substrate.

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SELOSTUS

Erilaisten ainesten soveltuvuus uuden torjuntaeliön, kirvasääsken koteloitumisalustaksi

Martti Markkula, Maija Rimpiläinen ja Katri Tiittanen

Maatalouden tutkimuskeskus, tuhoeläinosasto

Kasvihuoneviljelyksillä lehtikirvojen torjuntaan käytettävä kirvasääski (*Aphidoletes aphidimyza*) koteloituu maahan. Kun kirvasääsket lähetetään tilaajilleen koteloina, on tarpeellista tietää, minkälainen aines soveltuu parhaiten sääskien koteloitumisalustaksi.

Kokein selvitettiin seuraavien ainesten soveltuvuutta: hiekka, turve, vermikuliitti, perliitti ja vuorivilla sekä niiden erilaiset yhdistelmät.

Mikään tutkituista aineksista ei vaikuttanut kotelovaiheen pituuteen, ja ainoastaan perliitti vähensi aikuistumisen määrää. Turve todettiin erityisesti keveytensä perusteella soveliaimmaksi kirvasääsken koteloitumisalustaksi.

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ANNALES AGRICULTURAE FENNIAE, VOL. 18: 174—181 (1979)

Seria AGROGEOLOGIA ET -CHIMICA N. 90 — Sarja MAA JA LANNOITUS n:o 90

STRONTIUM CONTENT AND STRONTIUM-CALCIUM RATIO IN TIMOTHY (PHLEUM PRATENSE L.) AND SOIL IN FINLAND

ARJA PAASIKALLIO

PAASIKALLIO, A. 1979. **Strontium content and strontium-calcium ratio in timothy (Phleum pratense L.) and soil in Finland.** Ann. Agric. Fenn. 18: 174—181. (Agric. Res. Centre, Isotope Lab., SF-01300 Vantaa 30, Finland.)

Strontium and calcium contents were determined from about 2 000 sample pairs of timothy and soil. An investigation into these element contents was made with reference to parishes and latitudinal zones. The effect of some soil factors on the Sr content of timothy in Carex peat soil was also studied.

The Sr content of timothy was highest in northern Finland, while the highest contents of soluble Sr and Ca were generally found in the soils of southern Finland. The Ca content of timothy also tended to rise from the southern to the northern regions but to a lesser extent than Sr. The Sr/Ca ratio both in timothy and soil was generally highest between latitudes 64° and 66° N.

The highest Sr content of timothy in the north was suggested to be due to at least some of the following factors: regional differences in the distribution of soil types, the occurrence of nutritionally poorer soils in the northern regions, climatological factors and plant competition. The present material did not contain any exceptionally high Sr contents in timothy or soil.

In Carex peat, the Sr content of timothy increased with decreasing volume weight and pH of the soil. In these soils, the variation in the low Sr content of timothy was explained significantly by soluble Sr in the soil and the straw height; plant Sr increased with increasing soluble Sr and decreasing plant height. In higher Sr contents, plant Sr increased with decreasing soluble Ca.

Index words: Strontium, Sr/Ca ratio, timothy.

INTRODUCTION

Although strontium is not included as an essential element for plants and animals, the present interest in it is mostly due to the radioactive isotope of ^{90}Sr which is considered to be the most dangerous radionuclide produced by nuclear explosion.

The total and exchangeable strontium of Finnish soils have been studied by LAKANEN and SILLANPÄÄ (1967), and from the same 200 samples the strontium content of timothy has been studied by LAKANEN (1969). The material of the present investigation is from an extensive study on mineral elements in Finnish soils and plants (KÄHÄRI and NISSINEN 1978, PAASIKALLIO 1978 and SIPPOLA and TARES 1978). The Sr contents and the Sr/Ca ratios in timothy and soil are reported here in greater detail by parishes and latitudinal zones. Soil factors affecting the Sr content of timothy growing on Carex peat soils were also studied.

MATERIAL AND METHODS

Descriptions of analytical procedures as well as of collection and preparation of the sample material consisting of about 2 000 timothy-soil sample pairs have been given in detail by KÄHÄRI and NISSINEN 1978, PAASIKALLIO 1978 and SIPPOLA and TARES 1978. Sr and Ca were extracted from soil using acid ammonium acetate (pH 4,65). Plant and soil Sr and plant Ca were determined by atomic absorption spectrophotometry and soil Ca by flame photometry. The calcium-strontium discrimination factor (DF) was calculated as follows: $DF_{plant-soil} = Sr/Ca_{plant} : Sr/Ca_{soil}$ (MENZEL 1954). When there is no discrimination between Sr and Ca in the movement of these elements from soil to plant the DF will be equal to one and when there is a discrimination against Sr as compared with Ca, the DF will be less than one. However, the extractable amounts of Sr and Ca may not accurately represent the relative amounts available to the plant. For example, the exchangeable Ca may be underestimated and as a result, the DF will be too low and this underestimation will vary from soil to soil (SCHULZ et al. 1958, Ref. FREDRIKSSON et al. 1968). The element contents are reported in mg or g per kg plant dry matter.

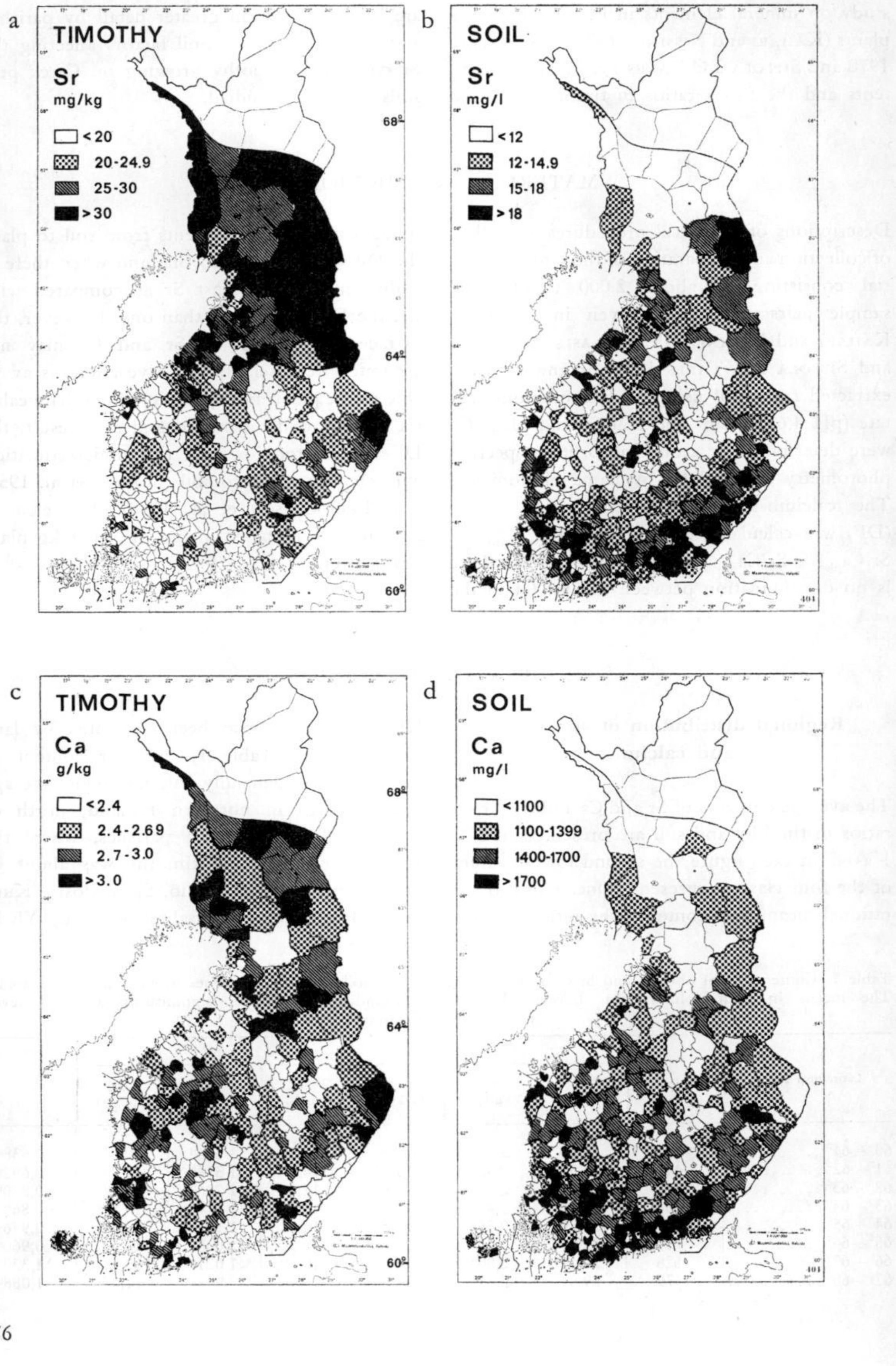
RESULTS AND DISCUSSION

Regional distribution of strontium and calcium

The average contents of Sr and Ca and the Sr/Ca ratios in timothy and soil are presented in Fig. 1 a—f. In each figure the second lowest values of the four classes represent values close to the rational mean. The contents, the ratios and the DF values have also been presented by latitudinal zones (Table 1). The Sr content of timothy was generally higher than average (22,8 mg/kg) in northern Finland; north of latitude 64° N. Northern parishes, where the average Sr content of timothy was about 40 mg/kg, included Enontekiö, Salla, Posio, Kuusamo, Puolanka, Hyrynsalmi, Kuhmo, Yli-Ii,

Table 1. Contents of Sr and Ca and Sr/Ca ratios in timothy and soil and the DF values in eight latitudinal zones. The means in each column not followed by the same index letter differ significantly at 95 % level. n = number of samples.

Latitudinal zones	n	Plant			Soil			DF
		Sr mg/kg	Ca g/kg	Sr/Ca (x 1 000)	Sr mg/l	Ca mg/l	Sr/Ca (x 1 000)	
60°—61°	197	15,8[a]	2,36[a]	6,79[a]	16,6[d]	1 656[d]	10,8[ab]	0,638[a]
61°—62°	441	18,5[a]	2,42[ab]	7,71[ab]	14,4[c]	1 376[c]	11,2[b]	0,692[a]
62°—63°	511	21,6[b]	2,68[c]	8,08[bc]	12,1[b]	1 286[bc]	10,2[a]	0,820[b]
63°—64°	288	21,2[b]	2,41[ab]	8,89[c]	11,8[ab]	1 217[abc]	10,5[ab]	0,869[bc]
64°—65°	183	31,2[c]	2,56[bc]	12,29[e]	14,4[c]	1 194[ab]	12,8[c]	0,976[cd]
65°—66°	117	32,9[c]	2,63[c]	12,83[e]	14,3[c]	1 038[a]	14,3[d]	0,960[bcd]
66°—67°	128	29,1[c]	2,90[d]	10,51[d]	10,2[ab]	1 021[a]	10,5[ab]	1,338[e]
67°—68°	79	29,6[c]	2,81[cd]	10,69[d]	9,4[a]	962[a]	11,0[ab]	1,088[d]


a
TIMOTHY
Sr
mg/kg
< 20
20-24.9
25-30
> 30
68°
64°
60°
b
SOIL
Sr
mg/l
< 12
12-14.9
15-18
> 18
c
TIMOTHY
Ca
g/kg
< 2.4
2.4-2.69
2.7-3.0
> 3.0
68°
64°
60°
d
SOIL
Ca
mg/l
< 1100
1100-1399
1400-1700
> 1700

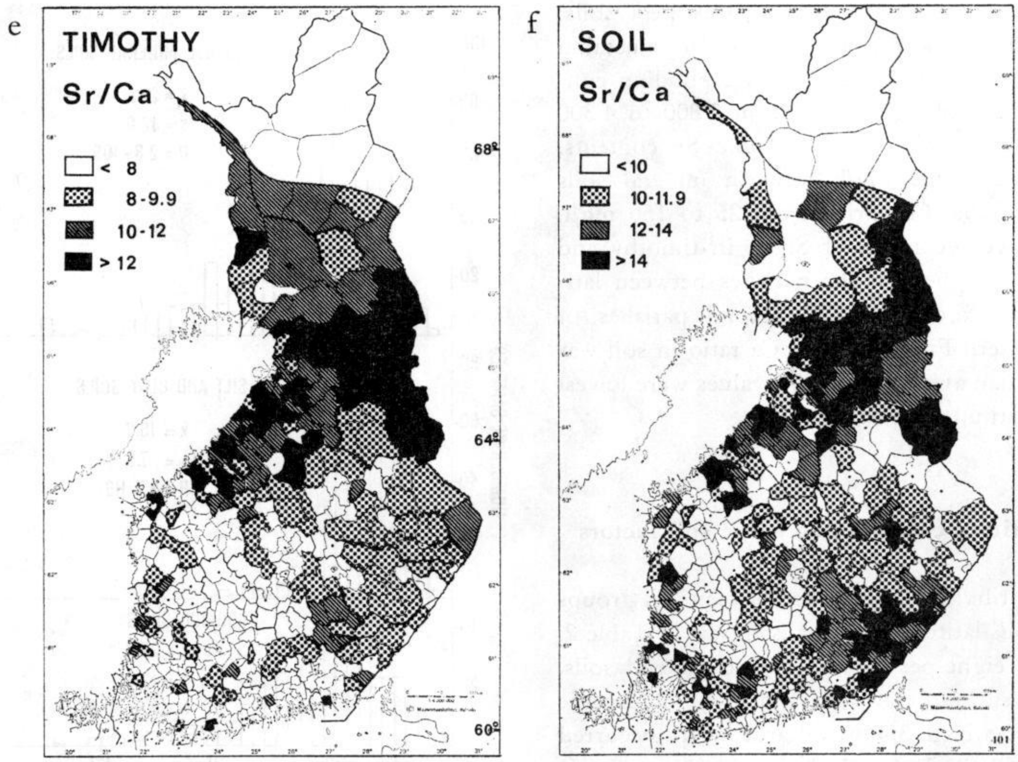


Fig. 1 a—f. Contents of Sr and Ca and Sr/Ca ratios in timothy and soil in various parishes. No samples were taken from the northernmost part of Finland (north of the transversal line at about 67°—68° N) where there is very little arable land.

Tyrnävä, Rantsila and Pyhäntä. The highest single Sr content of a timothy sample, 118 mg/kg, was found in plants grown on a sandy clay soil in Karjaa. Samples containing about 100 mg Sr/kg, were found in Suomussalmi in plants grown on glacial till and in Sodankylä on fine sand. South of latitude 64° N the Sr content of timothy was higher than 25 mg/kg only in some eastern parishes; i.e. in Ilomantsi, Eno, Tuupovaara, Kiihtelysvaara, Värtsilä and Tohmajärvi. The lowest Sr contents of timothy (below 15 mg/kg) were generally located in parishes of southern and southwestern Finland (between latitudes 60° and 62° N). The lowest single Sr contents (2,3—5,0 mg/kg) of timothy were most often found in coarse mineral soils. According to Lakanen (1969), the mean Sr content of timothy was 18,7 mg/kg; the maximum of 87,2 mg/kg was found in plants grown on organic soils and the Sr content of timothy decreased southwards where clay soils dominated. In soils rich in Sr, the Sr contents of plants may even rise above 1 % of D.M., among higher plants the lowest Sr contents are usually found in grasses (Bowen and Dymond 1955). These are only about one third of those found in legumes (Vose and Koontz 1960). The Ca contents of timothy were on average a little higher in the north and between latitudes 62° and 63° N than elsewhere. The Mg, P, Mn and Co (Kähäri and Nissinen 1978) and B (Paasikallio 1978) contents of timothy in the same material were also higher in the north than in the south.

Soluble Sr and Ca in soil were, on the other hand, highest in the southwestern, southern and southeastern parts of the country with some exceptions (e.g. relatively high amounts of soluble Sr were found in Kuusamo). The soluble contents of Mg, K, Co, Cu, Ni and Pb were also higher in the south than in the north (Sippola and Tares 1978). The highest single soluble Sr contents were in Carex peat soils; 47,3 mg/l in Juuka, 46,7 mg/l in Suomussalmi and 43,9 mg/l in Lemi; the corresponding contents of soluble Ca varied from 2 800 to 4 300 mg/l. The lowest single soluble Sr contents, from 0,2 to 0,5 mg/l, were in mineral soils where soluble Ca varied from 25 to 150 mg/l.

The average ratios of Sr/Ca in timothy and soil were highest in the parishes between latitudes 64° and 66° N. In several parishes of southeastern Finland the Sr/Ca ratio in soil was higher than average. The DF values were lowest below latitude 62° N.

Strontium, calcium and some soil factors

The distribution of samples between soil groups in various latitudinal zones is shown in Table 2. Twenty eight per cent of coarse mineral soils, 8 % of silt and clay soils and 41 % of organic soils (of which 3/4 was Carex peat) occurred north of latitude 64° N.

Table 2. Distribution of samples between soil groups in various latitudinal zones.

Latitudinal zones	Number of samples		
	Coarse mineral soils	Silt and clay soils	Organic soils
	n (%)	n (%)	n (%)
60°—61°	52 (26)	132 (67)	14 (7)
61°—62°	227 (50)	165 (37)	57 (13)
62°—63°	326 (63)	74 (14)	121 (23)
63°—64°	129 (43)	80 (27)	89 (30)
64°—65°	96 (52)	20 (11)	70 (37)
65°—66°	71 (61)	2 (2)	44 (37)
66°—67°	66 (50)	10 (8)	56 (42)
67°—68°	49 (62)	7 (9)	23 (29)

Fig. 2 shows the distribution of timothy samples among different classes of Sr content by three soil groups. About 40 per cent of the timothy samples collected from coarse mineral soils and from organic soils contained less than 20 mg Sr/kg while for silt and clay soils the respective figure was about 80 per cent. The contents of Sr and Ca in timothy and in soil by soil types have been reported earlier (Kähäri and Nissinen 1978, Paasikallio 1978 and Sippola and Tares 1978). The differences in the Sr/Ca ratio of soils between soil types were slight. In timothy, the ratio and the DF value were lowest in silt and clay soils (Table 3).

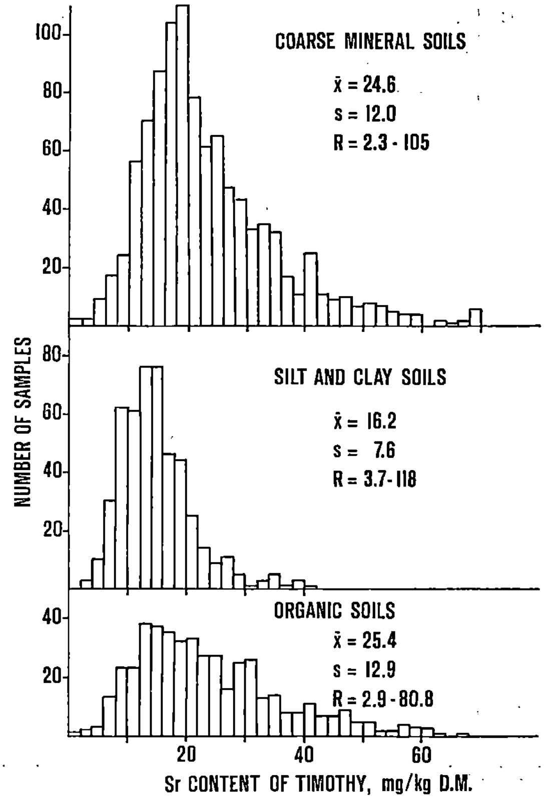


Fig. 2. Distribution of the timothy samples. $\bar{x}$ = mean, s = standard deviation and R = variation range.

The increase in the Sr content in timothy towards the north may be partly explained by the fact that most silt and clay soils occur in the southern parts. However, an increase in timothy Sr contents towards the north also occurred within individual soil types. For example, timothy samples from glacial till soils north of latitude 64° N contained significantly more Sr than samples from respective southern soils. The same was true for fine sand and for Carex peat soils (Table 4). Other soil types were not tested in this respect.

The Ca content of timothy was significantly higher in the north only in fine sand. The reduction in soluble Sr and Ca towards the north was observed most clearly in Carex peat

Table 3. Ratios of Sr/Ca in timothy and soil and the DF values in various soils. n = number of samples, $\bar{x}$ = mean value, s = standard deviation.

Soil Type	n		Plant Sr/Ca (x 1 000)	Soil Sr/Ca (x 1 000)	DF
Glacial till	295	$\bar{x}$	9,64	12,0	0,858
		s	4,52	4,7	0,619
Sand	51	$\bar{x}$	9,59	11,8	0,827
		s	4,21	4,7	0,219
Fine sand	456	$\bar{x}$	9,48	11,8	0,835
		s	3,94	4,5	0,297
Coarse silt	194	$\bar{x}$	9,53	11,2	0,928
		s	4,19	3,8	0,686
Silt	239	$\bar{x}$	7,63	10,3	0,764
		s	2,65	2,8	0,420
Silty clay	138	$\bar{x}$	7,10	9,7	0,736
		s	2,69	2,3	0,195
Sandy clay	69	$\bar{x}$	6,52	9,8	0,688
		s	5,31	2,7	0,626
Heavy clay	38	$\bar{x}$	6,08	10,2	0,599
		s	1,52	2,7	0,108
Gyttja	14	$\bar{x}$	9,84	10,4	1,010
		s	9,06	4,1	0,985
Mull	165	$\bar{x}$	8,08	9,9	0,851
		s	3,43	3,6	0,426
Carex peat	280	$\bar{x}$	10,22	11,3	0,984
		s	5,05	4,6	0,980
Sphagnum peat	5	$\bar{x}$	9,80	7,3	1,553
		s	5,20	5,1	0,808

Table 4. Contents of Sr and Ca in timothy and soil, soil pH and height of timothy by four latitudinal zones, in glacial till, fine sand and Carex peat soils, respectively. The means in each column not followed by the same index letter differ significantly at 95 % level (n = number of samples).

Latitudinal zones	n	Plant Sr mg/kg	Plant Ca g/kg	Soil Sr mg/l	Soil Ca mg/l	pH	Height of plant cm
Glacial till							
60°—62°	79	$22,7^{ab}$	$2,52^{a}$	$14,4^{c}$	$1\,144^{b}$	$5,68^{a}$	$74,7^{c}$
62°—64°	100	$22,3^{a}$	$2,62^{a}$	$10,5^{ab}$	$1\,057^{ab}$	$5,88^{b}$	$70,0^{b}$
64°—66°	57	$31,7^{c}$	$2,69^{a}$	$12,4^{bc}$	$1\,028^{ab}$	$5,87^{b}$	$59,8^{a}$
66°—68°	59	$28,3^{bc}$	$2,80^{a}$	$9,0^{a}$	901^{a}	$5,57^{a}$	$62,3^{a}$
Fine sand							
60°—62°	144	$20,3^{a}$	$2,51^{a}$	$13,7^{b}$	$1\,234^{b}$	$5,75^{a}$	$73,1^{b}$
62°—64°	218	$24,3^{b}$	$2,62^{a}$	$9,8^{a}$	$1\,006^{a}$	$5,71^{a}$	$66,6^{a}$
64°—66°	68	$32,3^{c}$	$2,51^{a}$	$11,9^{b}$	849^{a}	$5,62^{a}$	$65,7^{a}$
66°—68°	26	$28,1^{bc}$	$3,21^{b}$	$7,5^{a}$	810^{a}	$5,63^{a}$	$63,8^{a}$
Carex peat							
60°—62°	30	$19,3^{a}$	$2,65^{a}$	$23,6^{c}$	$2\,257^{b}$	$5,10^{b}$	$69,7^{b}$
62°—64°	103	$21,8^{a}$	$2,82^{ab}$	$18,9^{b}$	$2\,025^{b}$	$5,10^{b}$	$67,6^{b}$
64°—66°	89	$35,3^{b}$	$2,73^{a}$	$18,7^{b}$	$1\,411^{a}$	$5,01^{b}$	$60,2^{a}$
66°—68°	58	$32,5^{b}$	$3,12^{b}$	$12,8^{a}$	$1\,246^{a}$	$4,74^{a}$	$64,1^{ab}$

soils. The timothy was shortest in the north. Plant density was also sparser in the north compared with the whole country (KÄHÄRI and NISSINEN 1978).

The differences in the distribution of soil types between the northern and southern regions were thus not the only reason for the higher Sr content of timothy in the north. The poorer growth of timothy in the north might have been due to soil nutrient deficiency and, perhaps for this reason, the Sr content of the shorter timothy was higher than that of the taller plant in spite of possibly equal uptake (BEESON and MATRONE 1976). According to CHAPIN (1974), the roots of plants growing in cold soils had a higher capacity for ion uptake than plants in warmer soils. At least at the beginning of the growing period the temperature in the north is lower than farther south. Furthermore, »timothy is able to profit from the long day to the extent that its vegetative period is shortened northward and the flowering is progressively earlier in relation to the beginning of the growing season» (cf. DAUBENMIRE 1974).

The effect of some factors on the Sr content of timothy in Carex peat soil

As reported earlier (PAASIKALLIO 1978), soil exchangeable Ca and Sr had the greatest effect on the Sr content of timothy in the three soil groups; timothy Sr decreased with increasing Ca and decreasing Sr in soil. Of the cations in soil solution, Ca is known to have the greatest effect usually on the Sr uptake by a plant. In plants grown on organic soils the Sr decreased with increasing volume weight. This was mainly due to the smaller volume weight of the pure peat soils where also the Sr content of timothy was highest compared with other organic soils.

The variation in the Sr content of timothy was investigated here in more detail in two soil types; Carex peat and fine sand soils (including coarse silt). The following factors were chosen as independent variables for stepwise multiple regression analysis: soil Sr, Ca, Mg, K, P, C, pH, volume weight, and the height of timothy. The regression analysis was carried out for both low and high Sr contents in timothy. In Carex peat soil the variation of Sr in timothy (below 15 mg Sr/kg, $n = 50$) was explained significantly by soluble Sr in the soil ($F = 20,0$***) and the height of timothy ($F = 10,4$***); the Sr content of timothy increased with increasing soil Sr and decreasing straw height. The coefficient of determination was 34,8 %. In fine sand + coarse silt soils low in Sr ($n = 136$), none of the factors affected the variation.

In both soils the variation in Sr content of timothy containing over 25 mg Sr/kg was explained by soil Ca and Sr as in the earlier report. In Carex peat soils ($n = 143$) the coefficient of determination was 30,5 % and in fine sand + coarse silt soils ($n = 236$), where also soil K was an explaining factor, only 9,6 %.

In addition to the organic soils as a whole, the Sr content of timothy in Carex peat soils correlated negatively with volume weight ($r = -0,209$***) and with pH ($r = -0,138$*). No such correlation existed in mull. However, in both soil types the volume weight and pH correlated positively.

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SELOSTUS

Timoteiheinän ja maaperän Sr ja Sr/Ca-suhde Suomessa

Arja Paasikallio

Maatalouden tutkimuskeskus

Strontiumilla ei tiedetä olevan merkitystä eläinten ja kasvien ravitsemuksessa. Kiinnostus sitä kohtaan johtuu sen radioaktiivisesta isotoopista, ^{90}Sr:stä, jota pidetään ydinräjäytyksessä syntyvistä radionuklideista ihmiselle vaarallisimpana.

Tämä selvitys on täydennystä aikaisemmin suoritetuille tutkimuksille maaperän ja timotein Sr-pitoisuuksista Suomessa. Aineisto on peräisin laajasta, noin 2 000 näytettä käsittävästä, jo julkaistusta kivennäisainetutkimuksesta. Tässä selostetussa tutkimuksessa on päähuomio kiinnitetty Sr:n ja Ca:n alueelliseen jakautumiseen Suomessa. Lisäksi on tarkasteltu maaperätekijöiden vaikutusta timotein Sr-pitoisuuksiin.

Timotein ja maaperän Sr- ja Ca-pitoisuudet ja niiden suhteet on esitetty sekä kunnittain että leveyspiirivyöhykkeittäin (kuva 1 a—f, taul. 1). Timotein Sr-pitoisuus oli suurin pohjois-Suomessa, sitävastoin maan vaihtuva Sr ja Ca olivat suurimmat maan eteläosissa ja Sr/Ca-suhde sekä timoteissa että maassa oli suurin 64. ja 66. leveyspiirien välisellä alueella. Missään osissa maata ei kuitenkaan esiintynyt huomattavan korkeita timotein tai maaperän Sr-pitoisuuksia. Timotein Sr-pitoisuuden kasvaminen pohjoista kohden selitettiin osittain sillä että savimaat, joilla kasvaneella timoteilla oli kaikista maalajeista pienimmät Sr-pitoisuudet, ovat keskittyneet maan eteläosiin (taul. 2). Kuvassa 2 on esitetty timoteinäytteiden jakautuminen eri Sr-pitoisuusluokkiin kolmessa maalajiryhmässä. Sr- ja Ca-pitoisuudet timoteissa ja maassa maalajeittain on esitetty aikaisemmin. Sr/Ca-suhde timoteissa oli pienin hiesu- ja savimailla, samoin DF-arvot (taul. 3). Kun DF-arvo on pienempi kuin yksi, merkitsee se sitä että on tapahtunut Sr:n hylkiytymistä Ca:n suhteen siirryttäessä maasta kasviin. DF pätee kuitenkin vain siinä tapauksessa, että uuttoneste uuttaa maasta k.o. alkuaineita samassa suhteessa kuin ne ovat kasvin saatavissa.

Maalajisuhteiden erilaisuus pohjois- ja eteläosien välillä ei kuitenkaan ollut ainoa syy pohjoisosien suurempiin timotein Sr-pitoisuuksiin, sillä myös eri maalajien (moreeni, karkea hieta ja saraturve) sisällä timotein Sr ja jossakin tapauksessa myös Ca, suurenivat pohjoista kohden leveyspiirivyöhykkeittäin (taul. 4). Tämän seikan arveltiin johtuvan mm. pohjoisosien ravinneköyhemmästä maaperästä, mikä aiheutti timotein heikomman kasvun ja sen seurauksena Sr:n »rikastumisen» kasviin. Tämän lisäksi ilmastollisten tekijöiden erot maan etelä- ja pohjoisosien välillä sekä kasvien välinen kilpailu lienevät vaikuttaneet pohjoisten alueiden timotein Sr-pitoisuutta nostavasti.

ANNALES AGRICULTURAE FENNIAE, VOL. 18: 182—187 (1979)

Seria AGROGEOLOGIA ET -CHIMICA N. 91 — Sarja MAA JA LANNOITUS n:o 91

SELENIUM CONTENT OF SOILS AND TIMOTHY (PHLEUM PRATENSE L.) IN FINLAND

JOUKO SIPPOLA

SIPPOLA, J. 1979. **Selenium content of soils and timothy (Phleum pratense L.) in Finland.** Ann. Agric. Fenn. 18: 182—187. (Agric. Res. Centre, Inst. Soil Sci., SF-01300 Vantaa 30, Finland).

Selenium content of soil and timothy was analysed from 250 sites. Total selenium content in soil ranged from 5 to 1 241 µg/kg. High contents were generally found in clay soils and low contents in Carex peat soils. The content of ammonium acetate-Na_2 EDTA (pH 4,65) extractable selenium ranged from 1,3 to 67,1 µg/litre soil and was an average of 5 % of soil total selenium.

The selenium content of timothy ranged from 1,3 to 54,4 µg/kg with a mean of 7 µg/kg. The content was above 50 µg/kg, which is considered to be the minimum sufficiency limit for animals, in only one sample.

Of the determined soil factors affecting the selenium content of timothy, the total selenium in soil proved to be the most important. Soil organic matter content appeared to promote the uptake of selenium by timothy and high pH was shown to have a weak negative effect. The results of the method used to extract soluble selenium gave a poorer correlation with selenium content of timothy than soil total selenium.

Index words: Soil total selenium, soil extractable selenium, selenium in timothy.

INTRODUCTION

In Finland the low selenium content in forage crops has caused nutritional deficiences in animals which have led to considerable economical losses (OKSANEN 1965). The low selenium content of plants has been found to be relative to low contents in Finnish soils (KOLJONEN 1974). However, OKSANEN and SANDHOLM (1970) found no correlation between soil types and plant selenium content.

The low selenium content of Finnish soils is due to low contents in bedrock (KOLJONEN 1975). The dependence is most clear in glacial till soils (KOLJONEN 1974). In clay soils certain selenium enrichment has occurred during the weathering process. Selenium problems may be particularly expected on peat soils, which are cultivated extensively in Finland, because peat itself is composed of plant residues low in selenium. Small amounts of selenium may also be found in plants grown in coarse textured mineral soils, which are composed mostly of feldspar and quartz, and are therefore low in selenium.

The aim of this study was to obtain data concerning total and soluble selenium contents in soils and timothy in Finland and also to find relationships between soil factors affecting selenium contents in soils and plants.

MATERIAL AND METHODS

The study samples are a part of the material collected for the study on mineral elements in Finnish soils (SIPPOLA and TARES 1978). For the present study, 250 soil and timothy sample pairs covering the whole of Finland were taken (Fig. 1). The soil samples were prepared for determinations by air drying and passage through a 2 mm sieve. Soil organic carbon, texture and pH were determined as described by TARES and SIPPOLA (1978) and soluble selenium was extracted with acid ammonium acetate-0,02 M Na_2EDTA solution.

For soil total selenium, samples were finely pulverized in an agate mortar and then 0,5 g air dried soil was weighed into a teflon dish and, in the case of mineral soils, 10 ml 40 % HF, 2,5 ml 65 % HNO_3 and 2,5 ml 70 % $HClO_4$ were added. In the case of organic soils, 2,5 ml HF, 10 ml HNO_3 and 2,5 ml $HClO_4$ were added at the same concentrations. The suspension was allowed to stand overnight and heated the following day to a temperature of 120°C on an electric hot plate until most of the acids were evaporated and the volume of the residues was 1—2 ml. The suspension should not be heated to complete dryness because of the loss of selenium (BAJO 1978). The dishes were taken off the hot plate, 5 ml 2 M HCl was added and the dishes were returned to the hot plate for 30 minutes.

After cooling, samples were transferred into 25 ml volumetric flasks, diluted to 25 ml with 6 M HCl and poured off into polyethene flasks for determination.

The ammonium acetate-0,02 M Na_2EDTA soil extraction was prepared for determination by digesting 25 ml of extract with 2,5 ml HNO_3 and 0,5 ml $HClO_4$ in a sand bath. The tubes were heated until about 5 ml of the sample remained and then 1 ml 37 % HCl was added. This was heated for 30 minutes and filled with water to 10 ml final volume for determination.

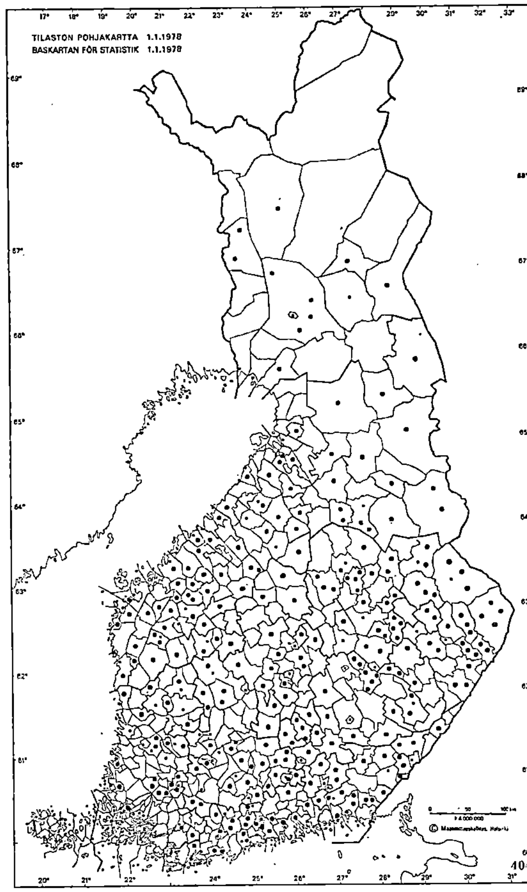

Fig. 1. Distribution of the soil and timothy sampling sites.

Plant samples were ashed using $Mg(NO_3)_2$ as described by SIEMER and HAGEMANN (1975). One gram of ground timothy was weighed into a 100 ml decanting glass, 8 ml saturated $Mg(NO_3)_2$ solution was added and the timothy was allowed to soak thoroughly. After evaporating to dryness on an electric hot plate, samples were kept in a muffle furnace at 450°C for 4 hours. To dissolve the ash, 2,5 ml water, 5 ml 37 % HCl and 5 ml 6 M HCl were used.

For selenium determination, the hydrogen-flushed hydride generation method of SIEMER and HAGEMANN (1975) and a Varian-Techtron AA-1 250 atomic absorption spectrophotometer were used. Standard solutions were prepared by diluting the stock solution prepared from elemental selenium with 6 M HCl. For each determination, 1 ml sodium borohydride (1 per cent solution) stabilized with a small amount of NaOH was used. Sample volumes measured into the reaction cell were 2 or 5 ml. Optimum flame conditions with the atomization tube used were 0,05 l/min O_2 and 2,1 l/min H_2.

An internal, standard method was used when analyzing ammonium acetate-Na_2EDTA soil extracts and timothy samples because the absorption of standard additions in these matrices were low compared to that in 6 M HCl. Double determinations of each sample solution was made. Each sample solution was prepared twice.

The method achieved a sensitivity of 0,6 ng Se (absorbance 0,0044) when 2 ml sample volumes were used. The relative standard deviation when determining standard solutions containing 10 ng selenium was 6 %. The relative standard deviation of double determinations of samples including preparations was approximately double.

RESULTS AND DISCUSSION

Total selenium in soil

The results of total selenium determinations ranged from 5 to 1 241 μg/kg soil. High contents were found in clay soils but also mull soils contained relatively large amounts of selenium (Table 1, Fig. 2). Carex peats had the lowest mean selenium content. In mineral soils, the mean total selenium content diminished with increasing particle size.

The maximum total selenium value found in this study (1 241 μg/kg) is higher than the maximum of 490 μg/kg found by KOLJONEN (1975) in a study of 22 samples of Finnish soils. The highest value does not, however, reach the level of seleniferous soils, which is 2 000 μg/kg (BISBJERG 1972). The means of clay and organic soils in the present study agree well with the results of KOLJONEN (1975), but in coarse mineral soils higher selenium contents were

Table 1. The properties of samples by soil types. Means with confidence limits at 95 % level.

Province	Number of samples	pH_{H_2O}	Org. C %	Total Se μg/kg	Soluble Se μg/l	Plant Se μg/kg
Heavy clay	14	5,8±0,3	4,3±1,0	360± 62	11,3±2,3	7,8±1,1
Silty clay	25	5,6±0,3	4,7±1,1	364± 51	16,7±2,1	10,6±1,5
Sandy clay	14	5,7±0,1	4,2±0,9	237±106	11,8±3,9	8,0±4,3
All clays	53	5,7±0,1	4,5±0,5	329± 54	14,0±2,4	9,2±2,0
Silt	35	5,7±0,2	3,7±0,8	195± 33	10,6±1,4	6,1±0,8
Finer finesand	34	5,7±0,2	3,4±0,5	176± 23	11,1±1,4	6,2±0,8
Finesand	44	5,7±0,1	4,0±0,7	151± 21	9,9±1,1	6,1±1,0
Till	29	5,9±0,2	3,4±2,5	143± 46	8,3±1,4	6,3±1,3
All coarse min. soils	142	5,7±0,1	3,7±0,3	166± 12	10,0±0,6	6,1±0,5
Mull	31	5,3±0,2	15,3±1,5	228± 71	11,6±2,2	7,7±3,3
Carex peat	24	5,1±0,2	33,6±0,5	93± 19	6,3±1,0	6,9±1,0
All organic soils	55	5,2±0,1	23,3±2,9	169± 48	9,3±1,6	7,3±1,9
All soils	250	5,6±0,1	8,1±1,2	201± 19	10,7±0,7	7,0±0,7

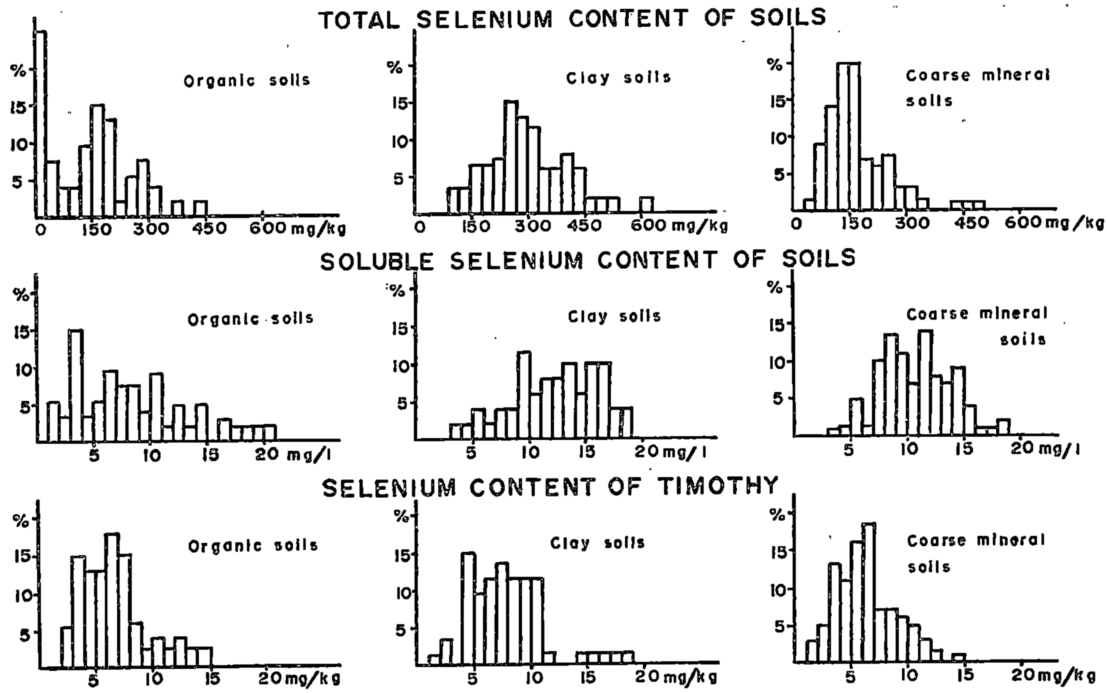

Fig. 2. Distributions of contents of soil total and soluble selenium and selenium content of timothy.

now determined. The difference may be due to cultivation, which KOLJONEN (1975) found to lead to an increased selenium level.

Total selenium contents similar to those found in Finnish soils have been reported in Swedish and Danish soils, where ranges from 165 to 970 and 160 to 1 500 µg/kg, respectively, were found (LINDBERG and BINGEFORS 1970, BISBJERG 1972).

Soluble selenium in soil

The content of acid ammonium acetate-Na_2EDTA extractable selenium ranged from 1,3 µg/l soil in a peat soil to 67,1 µg/l soil in the silty clay sample. In the latter sample the total selenium content was also the highest in the present material. Generally, the lowest contents of extractable selenium were in peat soils followed by coarse mineral soils (Table 1).

The combination of acid ammonium acetate and EDTA has not been used earlier to extract soil selenium. An average of 5 % of total selenium was extracted from soil in the present material. WILLIAMS and THORNTON (1973), using 0,05 M EDTA, found that 4,3—8,8 % of soil total selenium was extracted as opposed to only 1,8—2,2 % by water extraction. Water has been found to extract an average of 2,4 % of soil total selenium from Danish soils (HAMDY and GISSEL-NIELSEN 1976).

Selenium content in timothy

The selenium content of timothy ranged from 1,3 to 54,4 µg/kg. Lowest Se contents were found in timothy grown in a finesand soil and highest is that grown in a mull soil. In general, timothy grown in clay soils contained much selenium, while Se content of timothy grown in coarse mineral soils were the lowest.

The mean selenium content, 7 µg/kg, of timothy found in this study is lower than the 14 µg/kg reported earlier as a mean for samples collected from agricultural research stations in Finland (OKSANEN and SANDHOLM 1970).

Only in one sample was the selenium content above 50 µg/kg which is considered to be sufficient for animals. Only three samples fell into the range of 25—50 μg/kg indicating that the selenium content in Finnish timothy is extremely low.

Somewhat higher selenium contents of timothy than those determined in this study have been reported from Sweden with a range of 8 to 29 μg/kg. From Canada, a lower range of 5 to 23 μg/kg has been reported (Gupta and Winter 1975).

Selenium content of soil and timothy by regions

High contents of total and extractable soil were found in provinces where clay soils predominate (Uusimaa, Kymi, Turku and Pori) (Table 2). The selenium content of timothy in these provinces was also high but high selenium contents were also found in the provinces of Häme, Mikkeli, and Kuopio where clay soils are rare. Timothy from provinces along the Gulf of Bothnia, where nutritional selenium deficiencies have been found, contained little selenium. Timothy from the province of Lapland contained least selenium. This does not agree with the earlier findings of Oksanen and Sandholm (1970) who reported a mean selenium content of 5 timothy samples from the experimental station at Rovaniemi to be 39 μg/kg. Local variation, as also observed in the present study, may however explain this difference.

Table 2. Means of soil total and soluble selenium and selenium in timothy by provinces. Confidence limits at the 95 % level.

Province	n	In soil		Se in timothy μg/kg
		Total Se μg/kg	Soluble Se μg/l	
Uusimaa	19	301±70	13,3±2,1	7,4±1,0
Kymi	20	191±45	8,3±1,5	7,2±1,4
Turku and Pori	25	245±48	12,0±1,4	7,8±1,3
Häme	24	255±50	13,0±2,6	8,1±2,0
Mikkeli	24	222±99	12,7±5,2	8,7±3,2
Vaasa	35	161±27	11,0±1,4	5,5±0,6
Central Finland	16	167±48	9,8±2,1	5,5±1,1
Kuopio	24	214±83	10,1±2,1	7,2±3,2
North Karelia	24	211±89	9,5±2,4	7,3±1,5
Oulu	29	127±61	8,6±3,7	5,7±1,2
Lapland	10	121±22	8,7±1,0	4,4±0,8

Selenium content of soil and timothy as related to certain soil properties

Soil pH does not seem to correlate well with soil total selenium since a weak negative correlation (r = —0,50*) was found only in the group of heavy clay soils. With extractable selenium, there was a negative correlation with soil pH in clay soils (—0,29*) and in coarse mineral soils (—0,25*).

There was a weak negative correlation between soil pH and the selenium content of timothy only in the group of coarse mineral soils (Table 3). Between soil total and soluble selenium, the correlation coefficient was r = 0,65**, when all samples were included. Soil total selenium content was in closer correlation with selenium content of timothy than the soluble selenium content of soil.

Table 3. Significant coefficients of correlation of some soil factors on the selenium content of timothy in the different soil groups.

	pH	Total selenium	Soluble selenium
Organic soils	—	0,66**	0,38**
Clay soils	—	0,84**	0,71**
Coarse mineral soils	—0,17*	—	—

The organic carbon content of soils was in negative correlation with soil total selenium in the group of organic soils, r = —0,40*, which is in agreement with low selenium content of plants. Organic carbon was in positive correlation with the soil soluble selenium in the groups of clay and coarse mineral soils, r = 0,39** and 0,22**, respectively. Soil organic carbon did not correlate with selenium content of timothy.

An equation for multiple regression of selenium in timothy on soil total and soluble selenium, pH and organic carbon contents was calculated and the coefficients were as follows:

	total Se	soluble Se	pH	organic C	R
b	0,021	0,088	—0,36	0,067	0,66
β	0,60	0,10	0,03	0,12	

The coefficients indicate that total selenium was the most important factor in determining selenium content in timothy. The low β-coefficient value for soluble selenium does not encourage the application of the used extraction method for determining available Se in soils.

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SELOSTUS

Seleenipitoisuus maassa ja timoteissa Suomessa

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Maatalouden tutkimuskeskus

Eri puolilta maata 250 paikalta kerätyistä maa- ja timoteinäytteistä määritettiin seleenipitoisuus (Kuva 1). Seleenin kokonaismäärä vaihteli 5—1 241 μg/kg maata. Korkeimmat seleenipitoisuudet olivat savi- ja multamaissa (Taulukko 1, Kuva 2). Alhaisimmat pitoisuudet olivat turvemaissa. Seleenin kokonaismäärät maassa olivat samaa tasoa kuin muissa pohjoismaissa.

Maasta happamaan ammoniumasetaatti-Na_2EDTA-liuokseen uuttuvan seleenin määrä vaihteli 1,3—67,1 μg/litra maata. Vähiten liukoista seleeniä oli turvemaissa, joissa myös kokonaismäärä oli pieni.

Timotein seleenipitoisuus vaihteli 1,3—54,4 μg/kg keskiarvon ollessa 7 μg/kg. Korkeimmat seleenipitoisuudet olivat savimailla kasvaneessa timoteissa, alhaisimmat taas karkeilla kivennäismailla kasvaneessa. Vain yhden timoteinäytteen seleenipitoisuus oli yli 50 μg/kg, mitä pidetään vähimmäisvaatimuksena eläinten rehuissa.

Alueittain tarkasteltuna pienimmät kokonaisseleenin pitoisuudet olivat Lapin, Oulun ja Vaasan läänien maissa. Pieniä timotein seleenipitoisuuksia oli edellä mainittujen läänien lisäksi Keski-Suomen läänissä.

Timotein seleenipitoisuuteen vaikuttavista maaperätekijöistä osoittautui totaaliseleenin pitoisuus tärkeimmäksi. Orgaaninen aines näytti edistävän timotein seleenin saantia, kun taas korkea pH näytti lievästi vaikeuttavan sitä. Käytetyllä maan liukoisen seleenin määritysmenetelmällä saadut tulokset korreloivat timotein seleenipitoisuuden kanssa huonommin kuin maan seleenin totaalimäärät.

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Seria AGROGEOLOGIA ET -CHIMICA N. 92 — Sarja MAA JA LANNOITUS n:o 92

THE EFFECT OF MAGNESIUM, POTASSIUM AND NITROGEN FERTILIZERS ON THE CONTENTS AND RATIOS OF NUTRIENTS IN SPRING CEREALS AND GRASSLAND CROPS

RAILI JOKINEN

JOKINEN, R. 1979. **The effect of magnesium, potassium and nitrogen fertilizers on the contents and ratios of nutrients in spring cereals and grassland crops.** Ann. Agric. Fenn. 18: 188—202. (Agric. Res. Centre, Inst. Agric. Chem. and Phys., SF-31600 Jokioinen, Finland).

The effect of magnesium fertilizer (57 kg/ha Mg) on the contents and ratios of nutrients was investigated by means of field experiments at two levels of potassium chloride (60 and 240 kg/ha K) and at two levels of nitro-chalk (50 and 100 kg/ha N). Cereals was grown in the first two years of the experiments, grass in the third and fourth years and cereal again in the fifth year.

The use of magnesium fertilizer produced an increase in the magnesium content of spring cereal grain of only some 4%. Increasing the amount of potassium or nitrogen fertilizer had no effect on the result obtained with magnesium fertilizer. The magnesium content of cereal shoots correlated poorly with the grain yield.

The magnesium content of grassland stands increased significantly when magnesium fertilizer was used, both at the silage stage and in the hay and aftergrowth crops. At the same time there was a slight drop in the calcium content of the crops, and the K/(Ca + Mg) and K/Mg ratios diminished. The use of large quantities of potassium fertilizer reduced the magnesium content of the hay crop, whereas increasing the amount of nitrogen fertilizer caused it to rise.

An increase in the calcium content of the crop produced the greatest improvement in the (K/(Ca + Mg) ratio both at the silage stage and in the aftergrowth crop. In the hay crop the potassium content had a greater effect on this ratio than any other nutrient contents.

Index words: Magnesium, calcium, potassium content, K/Mg, K/(Ca + Mg).

INTRODUCTION

Increasing the amounts of magnesium, potassium and nitrogen fertilizers raises the contents of these nutrients in the stems and leaves of plants (SALONEN and TAINIO 1961, SALONEN et al. 1962, RINNE et al. 1974, KLAUSEN and LARSEN 1977, BAERUG 1977, JOKINEN 1977 a). The effect of fertilizers on the seed nutrient contents is less clear than its effect on the vegetative parts of the plant itself. The nitrogen content of cereal grain increases as the amount of nitrogen fertilizer increases (SALONEN et al. 1962). However, even the use of large amounts of potassium fertilizer failed to have any effect on the potassium content of cereal grain (SALONEN and TAINIO 1961, JOKINEN 1977 a).

The use of large quantities of potassium fertilizer on grassland may raise the potassium content of the crop to the point where the fodder endangers the health of livestock. The magnesium and calcium contents fall as a result of this increase in potassium content. In addition to the nutrient contents, the K/(Ca + Mg) and K/Mg ratios in the crop also give an indication of the value of the fodder (KEMP and t'HART 1957, JACOBSEN 1969). The effect of fertilizer on the ratios of nutrients in grassland species has been studied by MÄNTYLAHTI and MARJANEN (1971), MAYLAND et al. (1974), BAERUG (1977), KLAUSEN and LARSEN (1977), RINNE et al. (1978), and others.

This study investigates the effect of magnesium fertilizer on the contents and ratios of nutrients in grain and straw obtained from spring cereals and in the hay and aftergrowth crops from grassland as well as in samples taken at the silage stage. The result obtained with magnesium fertilizer was studied at two levels of potassium fertilizer and two levels of nitrogen fertilizer.

MATERIAL AND METHODS

The seven field experiments which form the basis for this study were carried out on low-magnesium soils whose plough layers (0—20 cm) had the following nutrient contents (extractable in acid ammonium acetate, pH 4,65):

Experiment no.	pH_{H_2O}	Acid ammonium acetate extractable, mg/l K	Ca	Mg
1.	5,6	124	1 180	100
2.	5,2	80	1 990	55
3.	6,2	275	1 290	54
4.	4,6	130	480	43
5.	5,2	111	370	50
6.	4,9	143	1 780	77
7.	5,6	128	1 170	26

The experiments investigate the effect of magnesium fertilizer (Mg_1 = 57 kg/ha Mg, as magnesiumsulphate) on the ratios and contents of nutrients in the grain and straw crops of spring cereals and in the crops harvested from grassland at two levels of potassium fertilizer (K_1 = 60, K_4 = 240 kg/ha K, as potassium chloride) and for two levels of nitrogen fertilizer (N_1 = 50, N_2 = 100 kg/ha N, as nitro-chalk). The first part of this study presents a detailed report on the field experiments and the crops obtained with the experimental treatments, and on changes in the nutrient state of the soil (JOKINEN 1978).

The average total yields (kg/ha/year dry matter) of cereal grain and grassland obtained over the five-year experimental period were as follows:

	N_1	N_1Mg	N_2	N_2Mg
Cereal				
K_1	2 940	2 970	3 050	3 140
K_4	2 900	2 960	2 940	2 990
Grassland				
K_1 hay crop	5 860	5 820	6 600	6 350
aftergrowth	1 240	1 160	1 980	1 990
K_4 hay crop	5 620	5 880	6 330	6 630
aftergrowth	1 010	1 050	1 830	1 930

Plant samples were taken from the experiments yearly for determination of nutrient contents. In addition to grain and straw samples, samples of shoots were also collected from cereal stands at the 4—5 leaf stage. The hay crop and aftergrowth were harvested from the grasslands and samples taken from each. In addition to these, samples were taken from grassland stands at the silage stage, although the crop was not harvested until the hay stage. The samples taken for analysis from grasslands were representative of the average botanical composition of the stand. The first-year grassland (3rd experimental year) in experiments 1 and 3 contained timothy grass with less than 10 % clover. The grassland species in the other experiments was timothy.

The plant samples were analysed for total nitrogen, using the Kjeldal method, and for total magnesium, calcium and potassium from the hydrochloric acid extract of the ash obtained from dry combustion (540° C), using the AAS method. The interference of other elements in the determination of calcium and magnesium was eliminated by making the solutions 0,25 % with respect to La. In the determination of potassium an air-propane flame and a wavelength of 7 665 Å were used; for calcium and magnesium determinations an air-acetylene flame was employed with a wavelength of 4 226 Å for calcium and 2 852 Å for magnesium. All results are expressed in mg/g of dry matter. The nutrient ratios K/Mg and K/(Ca + Mg) were calculated from the nutrient contents converted into milliequivalents.

The hectolitre weight of the grain yield was determined from three batches of 1/4 litre, and the seed weight from four batches of 100 seeds. At the time of the determinations the moisture content of the grain was c. 8 %.

It was not possible to test the effect of the experimental treatments on the nutrient contents of the crops from individual experiments since the samples obtained for analysis from several of the experiments represented the average stand of four replicates. In view of this the result for one year for each site was taken as a replicate, and the results of variance analysis indicate the average effect of the experimental treatments on the nutrient contents and ratios of each plant species in the material as a whole. The least significant difference ($LSD_{5\%}$) between potassium treatments, and the difference in nitrogen and magnesium treatments for one level of potassium fertilizer are presented separately in the tables. Correlation analysis was used to study the correlations between the various parameters. The statistical methods are the same as those used when testing the crop yields (Cochran and Cox 1966). In presenting the results most attention has been given to statistically significant changes. The combined effect of the nutrients given in the form of fertilizer on the nutrient contents and ratios was significant only in a few cases.

RESULTS

Nutrient contents and ratios of cereals

The magnesium content of shoot samples taken from cereals at the 4—5 leaf stage fell significantly when the amount of potassium fertilizer was increased fourfold (Table 1). The average drop in magnesium content was 0,13 mg/g (7 %). Magnesium fertilizer increased the magnesium content of the shoots by 22 % (1,48—1,81 mg/g); the increase was greater for the smaller potassium fertilizer level than for the larger.

In the first experimental year magnesium fertilizer raised the magnesium content of the shoots from 1,48 mg/g to 1,76 mg/g. In the fifth experimental year the increase was 0,51 mg/g (1,06—1,57 mg/g). Without magnesium fertilizer the magnesium content of the shoots was 28 % lower in the fifth year than in the first year. The cereal shoots grown on maddy finer finesand in experiment 4 showed clear signs of magnesium deficiency in the fifth year, when magnesium fertilizer was not used. The average magnesium content of these shoots was 0,78 mg/g, while that of shoots treated with magnesium fertilizer was 1,48 mg/g. Despite this there were no differences in grain yields. The magnesium content of the shoots and the grain yield (kg/ha dry matter) were poorly correlated (r = 0,236) in the material as a whole.

There was a slight positive correlation (r = 0,484**, b = 0,009) between the magnesium

Table 1. Magnesium content (Mg mg/g dry matter) of cereal shoots at the 4—5 leaf stage in the entire material, and separately for the first and fifth years ($\bar{x}$ = mean, s_d = standard deviation, w = range).

	K_1				K_4				$LSD_{5\%}$	
	N_1	N_1Mg	N_2	N_2Mg	N_1	N_1Mg	N_2	N_2Mg	K-levels	N-, Mg-treatments
The entire matherial										
$\bar{x}$	1,51	1,86	1,53	1,92	1,44	1,73	1,42	1,74	0,06	0,10
s_d	±0,42	±0,46	±0,37	±0,35	±0,43	±0,39	±0,44	±0,41		
w	0,74—2,27	1,25—2,88	0,76—2,14	1,46—2,55	0,68—2,29	1,23—2,57	0,71—2,51	1,16—2,59		
1st year										
$\bar{x}$	1,47	1,75	1,54	1,84	1,48	1,71	1,43	1,73		
w	1,24—1,88	1,49—1,96	1,35—1,83	1,64—2,12	1,28—2,11	1,50—2,03	1,23—1,87	1,51—2,22		
5th year										
$\bar{x}$	1,10	1,65	1,16	1,74	1,00	1,46	0,96	1,41		
w	0,76—1,54	1,25—2,42	0,76—1,55	1,46—2,40	0,68—1,37	1,23—2,06	0,72—1,20	1,17—1,87		

Table 2. Average magnesium, calcium, potassium and nitrogen contents (mg/g dry matter) in cereal grain ($\bar{x}$ = mean, s_d = standard deviation, w = range).

	K_1				K_4				$LSD_{5\%}$	
	N_1	N_1Mg	N_2	N_2Mg	N_1	N_1Mg	N_2	N_2Mg	K-levels	N-, Mg-treatments
Magnesium content										
$\bar{x}$	1,11	1,15	1,10	1,17	1,12	1,16	1,10	1,15	0,02	0,02
s_d	±0,17	±0,17	±0,20	±0,16	±0,21	±0,17	±0,20	±0,20		
w	0,78—1,35	0,85—1,45	0,69—1,36	0,84—1,46	0,55—1,41	0,81—1,41	0,61—1,39	0,84—1,49		
Calcium content										
$\bar{x}$	0,56	0,52	0,57	0,53	0,51	0,49	0,54	0,52	0,02	0,03
s_d	±0,12	±0,12	±0,14	±0,13	±0,13	±0,12	±0,13	±0,12		
w	0,36—0,75	0,29—0,75	0,35—0,84	0,29—0,78	0,32—0,77	0,31—0,74	0,36—0,78	0,31—0,73		
Potassium content										
$\bar{x}$	4,8	4,8	4,8	4,8	5,0	4,9	4,9	4,7	0,16	0,24
s_d	±1,2	±1,0	±1,2	±1,1	±1,1	±0,9	±1,0	±1,0		
w	3,3—8,2	3,3—6,4	2,5—7,0	3,3—7,3	3,4—7,0	3,2—6,5	3,2—6,3	3,1—6,3		
Nitrogen content										
$\bar{x}$	21,3	21,4	23,4	23,7	21,8	21,5	23,2	23,9	0,39	0,64
s_d	±3,6	±3,7	±3,3	±3,7	±3,9	±3,9	±3,1	±3,1		
w	14,7—28,8	14,7—28,2	17,0—31,1	19,1—31,5	15,9—28,2	14,5—27,9	16,8—28,1	16,7—28,6		

content of the shoots and the magnesium content (extractable in acid ammonium acetate) of soil samples taken in the spring before application of fertilizer. The potassium content of the soil had no effect on the magnesium content of the shoots, and variations in the K/Mg ratio in the soil did not depict changes in the magnesium content of the shoots ($r = —0,444^{**}$, $b = —0,220$) any better than variations in the soil magnesium content.

The experimental treatments caused only slight changes in the *magnesium content of the cereal grain* (Table 2). Only magnesium fertilizer produced any significant increase in the grain magnesium content, the increase being on average 0,05 mg/g (1,11—1,16 mg/g, 4 %). Magnesium fertilizer raised the magnesium content by an average of 0,03 mg/g (3 %) in the first year, 0,04 mg/g (3 %) in the second year and 0,08 mg/g (9 %) in the fifth year. The soil magnesium content, potassium content and K/Mg ratio had no significant effect on the magnesium content of the grain.

A fourfold amount of potassium fertilizer brought about an average drop of 5 % (0,03 mg/g) in the *grain calcium content*. Magnesium fertilizer also caused a reduction in grain calcium content. Each of the two fertilizers caused a significant drop in the grain calcium content irrespective of the amount of the other.

Grain grown with the larger amount of nitrogen fertilizer contained an average 6 % (0,02 mg/g) more calcium than grain obtained with the smaller amount of nitrogen. There was poor correlation between the soil potassium content and the calcium content of the grain (r = —0,307**, b = —0,001).

The grain potassium content did not appear to depend on the fertilizers used in this study. A fourfold amount of potassium fertilizer produced a slight increase in the grain potassium content only for the smaller amount of nitrogen. There were large differences in potassium content between sites and between experimental years. The soil potassium content appeared to have a weak positive correlation with the potassium content of the grain (r = 0,428**, b = 0,006).

The grain nitrogen content increased significantly (1,0 mg/g, 10 %) when the nitrogen fertilizer level was increased from 50 kg to 100 kg. The other treatments used in this study had no effect on the nitrogen content.

The hectolitre weight and seed weight, the properties depicting the external quality of the grain crop, were only slightly affected by a fourfold amount of potassium fertilizer. The hectolitre weight increased by 0,42 kg (1 %) and the seed weight by 0,36 mg (1 %). Doubling the amount of nitrogen fertilizer reduced the hectolitre weight of the grain crop by 1,14 kg (2 %), since 100 kg/ha of nitrogen caused lodging on soil with a high humus content. Changes in the soil nutrient content did not bring about any changes in the hectolitre weight or seed weight.

The magnesium content of the straw was highest with the smaller amount of potassium, and fell significantly (0,74—0,67 mg/g, 10 %) when the amount of potassium fertilizer was increased fourfold (Table 3). The larger amount of potassium reduced the magnesium content of the straw most clearly in crops treated with magnesium fertilizer. Doubling the amount of nitrogen fertilizer raised the magnesium content of the straw by 10 % (0,67—0,74 mg/g) and treatment with magnesium fertilizer increased it by 17 % (0,65—0,76 mg/g).

Magnesium fertilizer produced an increase of 11 % (0,74—0,82 mg/g) in the magnesium content of the straw in the first experimental year, an increase of 12 % (0,65—0,73 mg/g) in the second year and an increase of 44 % (0,54—0,78 mg/g) in the fifth year. Without magnesium fertilizer the magnesium content of the straw was in the fifth year 27 % lower than in the first year. The annual application of magnesium fertilizer appeared to maintain the magnesium content of the straw at almost the same level throughout the experimental period.

There was no clear correlation between the magnesium content of the straw and fluctuations in the soil magnesium content, potassium content or K/Mg ratio.

Table 3. Magnesium, calcium and potassium contents (mg/g dry matter) in cereal staw ($\bar{x}$ = mean, s_d = standard deviation, w = range).

	K_1				K_4				LSD 5 %	
	N_1	N_1Mg	N_2	N_2Mg	N_1	N_1Mg	N_2	N_2Mg	K-levels	N-, Mg-treatments
Magnesium content										
$\bar{x}$	0,62	0,76	0,71	0,87	0,60	0,69	0,66	0,73	0,05	0,07
s_d	±0,22	±0,25	±0,25	±0,30	±0,27	±0,22	±0,25	±0,20		
w	0,20—1,14	0,48—1,41	0,19—1,41	0,46—1,65	0,09—1,23	0,30—1,21	0,10—1,18	0,30—1,20		
Calcium content										
$\bar{x}$	2,61	2,42	3,00	2,78	2,52	2,25	2,80	2,54	0,15	0,20
s_d	±0,92	±0,81	±0,93	±0,92	±1,17	±0,83	±1,14	±0,90		
w	0,80—5,15	0,84—4,27	0,85—4,24	0,93—4,69	0,77—5,94	0,85—4,31	0,78—5,84	0,78—4,44		
Potassium content										
$\bar{x}$	19,1	19,0	19,7	20,2	21,3	21,5	24,5	24,6	1,24	1,52
s_d	±7,9	±7,4	±7,4	±8,5	±8,2	±8,4	±8,1	±9,0		
w	4,2—36,9	5,5—35,4	8,6—34,6	8,7—37,9	8,0—39,4	8,0—38,9	9,4—40,3	7,0—40,6		

The calcium content of the straw decreased significantly (2,70—2,53 mg/g, 6 %) when the amount of potassium fertilizer was increased fourfold. Magnesium fertilizer also had a similar effect (2,74—2,50 mg/g, 9 %) irrespectice of the amount of nitrogen fertilizer used. The crops obtained using the larger amount of nitrogen contained significantly more calcium than those grown with smaller amounts of nitrogen (2,45—2,78 mg/g, 14 %). An increase in the soil potassium content caused a slight drop in the calcium content of the straw (r = —0,473** b = —0,006).

A fourfold amount of potassium fertilizer and a twofold amount of nitrogen fertilizer both produced significant increases in the *potassium content* of the straw, the increases being 18 % (19,5—23,0 mg/g) and 10 % (20,2—22,2 mg/g), respectively. With the smaller amount of potassium an increase in the level of nitrogen fertilizer did not affect the potassium content of the straw, while for the larger amount of potassium the difference in potassium content for the two nitrogen levels was significant. As the potassium content of the soil increased, the potassium content of the straw also increased (r = 0,574**, b = 0,085).

Nutrient contents and ratios of grassland at the silage stage

Samples of the stand were taken from the grassland for analysis at the silage stage, although the crop was not harvested at this stage. In this way it was possible to compare the nutrient contents in the stands at the various stages of growth.

Magnesium fertilizer increased the average *magnesium content* of the stand by 44 % (1,11—1,61 mg/g), the increase being significant at both levels of potassium and nitrogen fertilizers (Table 4). The increase in magnesium content was greatest in experiment 7, in which the finer finesand soil had a magnesium content of 26 mg/l. The magnesium content of the stand at the silage stage was not changed significantly by a fourfold potassium fertilizer level (1,42—1,30 mg/g, 8 %) or by a twofold nitrogen fertilizer level (1,30—1,42 mg/g, 9 %). Magnesium fertilizer increased the magnesium content

Table 4. Magnesium, calcium and potassium contents (mg/g dry matter) and the values of the K/Mg and K/(Ca + Mg) ratios (me) of grassland at the silage stage ($\bar{x}$ = mean, s_d = standard deviation, w = range).

	K_1				K_4				LSD 5 %	
	N_1	N_1Mg	N_2	N_2Mg	N_1	N_1Mg	N_2	N_2Mg	K-levels	N-, Mg-treatments
Magnesium content										
$\bar{x}$	1,08	1,55	1,26	1,78	0,98	1,60	1,14	1,49	0,15	0,31
s_d	±0,30	±0,28	±0,16	±0,34	±0,22	±0,82	±0,18	±0,23		
w	0,78—1,67	1,13—1,90	1,04—1,53	1,38—2,39	0,73—1,30	0,98—1,59	0,98—1,44	1,11—1,78		
Calcium content										
$\bar{x}$	3,88	3,41	4,58	4,10	3,69	3,16	4,28	3,59	0,21	0,36
s_d	±0,87	±1,05	±0,55	±0,66	±0,92	±0,97	±0,53	±0,78		
w	2,84—5,37	2,53—5,36	3,95—5,47	3,35—5,23	2,76—5,18	2,24—4,66	3,81—5,21	2,80—4,67		
Potassium content										
$\bar{x}$	37,0	37,8	41,9	42,0	40,0	39,2	46,2	44,1	1,10	3,09
s_d	±4,5	±5,7	±6,0	±6,2	±7,1	±6,9	±6,3	±6,4		
w	31,7—44,9	29,5—46,5	36,1—49,6	37,7—51,8	32,3—50,4	31,1—49,8	36,9—55,5	36,4—54,1		
K/Mg										
$\bar{x}$	11,4	7,7	10,4	7,4	13,0	9,2	12,8	9,3	0,61	1,32
s_d	±2,9	±1,4	±0,8	±0,8	±2,1	±1,6	±1,3	±1,2		
w	6,8—14,8	5,4—10,1	8,9—11,4	6,3—8,5	9,0—14,5	6,5—11,4	10,4—14,6	7,1—10,8		
K/(Ca + Mg)										
$\bar{x}$	3,5	3,3	3,2	3,0	3,9	3,8	3,9	3,8	0,25	0,28
s_d	±0,8	±0,7	±0,4	±0,3	±0,8	±0,8	±0,5	±0,6		
w	2,3—4,2	2,1—3,9	2,6—3,9	2,5—3,3	2,4—4,9	2,5—4,9	2,9—4,5	2,6—4,4		

at the silage stage on the first year ley (3rd experimental year) by 30 % (1,12—1,46 mg/g) and by 63 % on the second year ley (1,11—1,81 mg/g). There was a slight positive correlation in this material between the magnesium content of the stand and that of the soil determined before the application of fertilizers (r = 0,406**, b = 0,005). Fluctuations in the soil potassium content or the K/Mg ratio did not change the magnesium content of the stand.

Magnesium fertilizer significantly reduced the *calcium content* of the stand (4,11—3,37 mg/g, 18 %), the drop in calcium content being more noticeable for the higher potassium level than for the lower. Increasing the potassium fertilizer fourfold brought about an average decrease of 8 % (3,99—3,68 mg/g) in the calcium content of the stand. Increasing the nitrogen fertilizer twofold raised the calcium content of the stand significantly (3,54—4,14 mg/g, 17 %).

The *potassium content* of the stand was particularly high for both levels of potassium fertilizer in this material. The potassium content increased significantly as a result of increasing both the amount of nitrogen fertilizer (38,5—43,6 mg/g, 13 %) and the amount of potassium fertilizer (39,7—42,2 mg/g, 7 %). At the higher potassium level, magnesium fertilizer appeared to cause a slight, although not significant, reduction in the potassium content of the stand. The potassium content of the stand was affected only slightly by the soil potassium content (r = 0,115), magnesium content (r = —0,286*) and K/Mg ratio (r = 0,320*).

At the silage stage the stand contained ten times more potassium, on average, than magnesium, in terms of equivalents. The *K/Mg* (me) ratio in the crops obtained using different treatments varied in the range 7,4—13,0. The higher level of potassium fertilizer increased the ratio by 20 % (9,2—11,1). Magnesium fertilizer significantly reduced the ratio (11,9—8,4, 29 %), the result being independent of the nitrogen and potassium fertilizer levels. The amount of nitrogen fertilizer had no effect on the value of the ratio. Increasing the magnesium content of the crop changed the K/Mg ratio in the stand more (r = —0,659**, b = —3,763) than did a reduction in the potassium content (r = 0,202, b = 0,078).

The ratio of potassium to the sum of calcium and magnesium (me) at the silage stage in stands was high, averaging 3,6. Both a fourfold increase in potassium fertilizer and a twofold amount of nitrogen fertilizer had a significant effect on the K/(Ca + Mg) ratio: potassium fertilizer increased the ratio by 18 % (3,3—3,9) and nitrogen fertilizer reduced it by 5 % (3,7—3,5). Magnesium fertilizer did not change the value of the ratio at any of the potassium or nitrogen levels. As the calcium content of the stand increased the K/(Ca + Mg) ratio fell (r = —0,678**, b = —0,519), whereas increasing the magnesium content had only a slight effect (r = —0,134, b = —0,224). As the potassium content increased there was a slight increase in the value of the ratio (r = 0,424**, b = 0,044).

Nutrient contents and ratios in the hay crop

The average *magnesium content* (0,93 mg/g) of the crop harvested as dry hay was almost 30 % lower than that of the stand at the silage stage (1,36 mg/g). The crops harvested from first-year leys contained almost as much magnesium (average 0,97 mg/g) as crops from second year leys (0,90 mg/g).

Magnesium fertilizer had a more pronounced effect on the magnesium content of the hay crop than any of the other treatments used in this study (Table 5). Magnesium fertilizer raised the magnesium content by an average of 34 % (0,80—1,07 mg/g), the increase being independent of the potassium and nitrogen fertilizer levels. Increasing the fertilizer nitrogen from 50 to 100 kg raised the magnesium content by an average 10 % (0,89—0,98 mg/g), whereas increasing the fertilizer potassium from 60 kg to 240 kg reduced the magnesium content by 9 % (0,98—0,89 mg/g). There was a positive correlation between the magnesium content of the hay crop and the soil magnesium content determined in spring before the application of fertilizer (r = 0,649**, b = 0,005). The magne-

Table 5. Magnesium, calcium, potassium and nitrogen contents (mg/g dry matter) and the values of the K/Mg and K/Ca + Mg) ratios in the dry hay crop from grassland ($\bar{x}$ = mean, s_d = standard deviation, w = range).

	K_1				K_4				$LSD_{5\%}$	
	N_1	N_1Mg	N_2	N_2Mg	N_1	N_1Mg	N_2	N_2Mg	K-levels	N-, Mg-treatments
Magnesium content										
$\bar{x}$	0,76	1,08	0,90	1,17	0,73	0,99	0,80	1,05	0,02	0,08
s_d	±0,14	±0,17	±0,14	±0,18	±0,16	±0,19	±0,12	±0,16		
w	0,52—1,02	0,74—1,34	0,62—1,12	0,79—1,46	0,45—0,96	0,59—1,20	0,59—1,01	0,79—1,32		
Calcium content										
$\bar{x}$	2,96	2,61	3,30	2,89	2,80	2,48	3,18	2,74	0,13	0,23
s_d	±0,63	±0,65	±0,59	±0,51	±0,69	±0,68	±0,48	±0,58		
w	2,17—3,91	1,76—3,93	2,59—4,63	1,99—3,72	1,65—3,65	1,51—3,57	2,52—4,06	1,96—3,70		
Potassium content										
x	24,6	25,3	27,2	25,6	27,9	27,6	31,3	30,2	1,05	1,63
s_d	±6,8	±6,4	±6,8	±3,6	±5,9	±6,8	±7,0	±7,2		
w	12,1—36,3	14,7—38,0	16,3—43,1	16,1—29,4	18,3—38,8	16,6—41,0	19,7—44,3	17,6—44,3		
Nitrogen content										
$\bar{x}$	14,5	14,8	18,1	17,3	14,6	14,9	18,3	17,6	0,48	1,11
s_d	±3,3	±3,7	±5,4	±4,3	±3,9	±4,4	±5,1	±4,5		
w	7,2—19,5	7,0—20,4	10,8—29,9	9,4—24,4	7,0—19,8	6,8—22,6	9,7—29,7	9,5—25,6		
K/Mg										
$\bar{x}$	10,2	7,3	9,4	6,9	12,2	8,8	12,2	9,0	0,57	1,02
s_d	±3,0	±1,6	±1,9	±1,0	±3,0	±1,9	±2,4	±2,0		
w	4,5—14,7	4,4—9,6	6,4—13,4	5,6—8,8	7,4—17,1	5,5—11,9	9,0—17,0	6,3—13,1		
K/(Ca + Mg)										
$\bar{x}$	3,0	3,0	2,9	2,7	3,7	3,5	3,6	3,5	0,21	0,26
s_d	±0,8	±0,7	±0,6	±0,3	±0,9	±0,8	±0,7	±0,8		
w	1,6—4,2	1,8—3,8	2,1—4,2	2,4—3,5	2,2—5,5	2,0—5,0	2,6—5,1	2,5—5,1		

sium content of the crop fell as the potassium content of the soil increased (r = —0,259*) and as the K/Mg ratio increased (r = —0,533**).

The calcium content of the hay crop (2,87 mg/g) was around 25 % lower than the calcium content of the stand at the silage-stage (3,84 mg/g). At twofold level of nitrogen fertilizer raised the calcium content of the hay by 11 % (2,71—3,03 mg/g), whereas a fourfold potassium fertilizer level reduced the calcium content by 5 % (2,94—2,80 mg/g). Magnesium fertilizer reduced the calcium content by 12 % (3,06—2,68 mg/g).

The potassium content of the crop also showed a clear drop in going from the silage stage (41,0 mg/g) to the crop harvested as dry hay (27,4 mg/g). A fourfold amount of potassium fertilizer raised the potassium content of the hay by 14 % (25,7—29,2 mg/g): doubling the nitrogen fertilizer level had a similar effect (26,3—28,6 mg/g, 9 %).

Increasing the nitrogen level from N_1 to N_2 produced a significant increase in the *nitrogen content* of the hay crop (14,7—17,8 mg/g, 21 %). The other treatments used in this study did not produce any significant changes in the nitrogen content.

The ratio of potassium to magnesium (me) was 9,5 in the hay crop, almost as high as in the stand at the silage stage (10,1). In this material the ratio of these nutrients did not appear to show any change as the age of the stand increased. The effects of the experimental treatments on the K/Mg ratio of the hay crop were almost the same as those on the nutrient ratio in the stand at the silage stage. A fourfold amount of the potassium fertilizer level brought about a significant increase in the ratio (8,4—10,5, 25 %), whereas magnesium fertilizer caused a decrease (11,0—8,0, 27 %). The reduction in the K/Mg ratio brought about by the magnesium fertilizer was slightly more pronounced for the higher potassium level than for the lower. The dependence of the K/Mg ratio in the hay crop on fluctuations in the magnesium content of the crop (r = —0,572**) or in potassium content of the crop (r = 0,563**) was of the same order, though in different directions. There was a significant correlation (r = –0,584**) between the soil magnesium content and the K/Mg ratio in the hay crop.

The ratio of potassium to the sum of calcium and magnesium (me) averaged 3,2 in the hay crops and 3,6 in stands at the silage stage. There was only a slight change in the ratio. The higher level of potassium fertilizer significantly raised the K/(Ca + Mg) ratio (2,9—3,6, 23 %). The ratios showed that the crops contained an abundance of potassium for both levels of potassium fertilizer compared with the sum of magnesium and calcium. Neither the use of magnesium fertilizer nor doubling the amount of nitrogen fertilizer had any significant effect on the ratio.

There was no difference in the nutrient ratios of the hay crops harvested from first or second year leys (3,2 and 3,3). An increase of 1 mg/g in the magnesium content of the hay crop reduced the K/(Ca + Mg) ratio by 0,942 (r = —0,260*) and a similar increase in the calcium content reduced it by 0,399 (r = —0,326*). Raising the potassium content increased the nutrient ratio (b = 0,073, r = 0,586**). Fluctuations in the soil potassium content (r = 0,386**, b = 0,004) on the soil magnesium content (r = —0,316**, b = —0,008) produced only slight changes in the K/(Ca + Mg) ratio.

In every experimental treatment carried out on clayey finer finesand soil (experiment 1) the hay crop from the first year ley contained clover. The *magnesium, potassium and calcium contents of the clover and the ratios of the nutrients* were as follows:

	N_1	N_1Mg	N_2	N_2Mg
Magnesium content				
K_1	2,28	2,90	2,37	2,71
K_4	2,28	2,69	2,19	2,53
Calcium content				
K_1	11,82	11,39	12,07	10,92
K_4	10,99	10,49	12,29	12,10
Potassium content				
K_1	22,8	28,9	28,7	29,7
K_4	34,4	32,7	34,1	33,7
K/Mg (me)				
K_1	3,1	3,1	3,7	3,4
K_4	4,7	3,8	4,8	4,1
K/(Ca + Mg) (me)				
K_1	0,7	0,9	0,9	1,0
K_4	1,2	1,1	1,1	1,1

The calcium content of the clover was about three times higher than for the stand as a whole in this experiment, and the magnesium content was almost double, whereas the K/Mg and K/(Ca + Mg) ratios (me) were considerably lower. The changes in nutrient contents of the clover due to the experimental treatments were similar to those in the stand as a whole.

Nutrient contents and ratios in the aftergrowth crop

No fertilizer was spread on the experimental plots after the hay crop had been harvested. For this reason the aftergrowth crop was small and in some experiments no second crop was obtained at all.

The average *magnesium content* of the aftergrowth crop (1,18 mg/g) was lower than that in the samples taken at the silage stage, but higher than the magnesium content of the hay crop. The application of magnesium fertilizer in spring significantly increased the magnesium content of the aftergrowth crop (1,00—1,37 mg/g, 37 %, Table 6). The effect of magnesium fertilizer was clearly more advantageous for the smaller nitrogen level than for the larger; the magnesium contents of the crop were as follows:

	Mg_0	Mg_1
N_1	1,04	1,54
N_2	0,96	1,21

The average reduction in the magnesium content of the aftergrowth crop produced by the higher nitrogen level was significant (0,20 mg/g, 16 %). A reduction was found in all the experiments, with particularly marked differences in experiment 4 (maddy finer finesand). The effect of the magnesium content of the

Table 6. Magnesium, calcium and potassium contents (mg/g dry matter) and the values of the K/Mg and K/(Ca + Mg) ratios in the aftergrowth crop from grassland ($\bar{x}$ = mean, s_d = standard deviation, w = range).

	K_1				K_4				LSD 5 %	
	N_1	N_1Mg	N_2	N_2Mg	N_1	N_1Mg	N_2	N_2Mg	K-levels	N-, Mg-treatments
Magnesium content										
$\bar{x}$	1,13	1,64	0,95	1,35	0,95	1,42	0,96	1,07	0,25	0,22
s_d	±0,54	±0,72	±0,38	±0,42	±0,39	±0,76	±0,67	±0,35		
w	0,64—2,36	1,01—2,75	0,56—1,71	0,94—1,85	0,47—1,95	0,92—3,46	0,43—2,70	0,67—1,94		
Calcium content										
$\bar{x}$	5,68	5,53	4,14	4,38	5,08	4,82	4,03	3,58	0,38	1,00
s_d	±2,97	±3,22	±1,35	±1,82	±2,50	±2,67	±1,17	±1,09		
w	3,13—11,41	2,64—11,81	2,82—7,37	2,58—8,69	2,63—10,12	2,47—10,31	3,24—5,81	2,54—5,55		
Potassium content										
$\bar{x}$	22,8	22,2	21,3	21,2	23,6	23,2	23,2	22,4	0,90	1,49
s_d	±2,1	±2,1	±3,7	±2,7	±2,5	±2,2	±3,2	±4,0		
w	19,7—25,6	17,6—25,3	14,2—26,0	16,5—24,5	18,6—27,7	17,3—25,6	18,4—28,1	13,4—26,4		
K/Mg										
$\bar{x}$	7,3	4,8	7,6	5,2	8,8	5,9	9,4	7,0	1,21	0,98
s_d	±2,5	±1,7	±2,3	±1,5	±3,2	±1,9	±3,7	±2,1		
w	3,2—9,9	2,7—7,3	4,1—10,6	3,5—7,2	3,7—15,6	2,1—7,8	2,6—16,1	3,9—9,8		
K/Ca + Mg)										
$\bar{x}$	1,8	1,6	2,0	1,8	2,1	2,0	2,4	2,2	0,28	0,19
s_d	±0,7	±0,6	±0,5	±0,5	±0,9	±0,8	±0,9	±0,8		
w	0,8—2,6	0,8—2,5	1,1—2,6	1,2—2,4	0,9—3,5	0,8—2,8	1,2—2,8	1,2—3,0		

soil, measured in spring, on the magnesium content of the aftergrowth crop was slight (r = 0,424**, b = 0,011). The same applies to the effect of the soil potassium content (r = —0,235*, b = —0,002).

The calcium content of the aftergrowth crop (4,62 mg/g) was higher than that in samples taken at the silage stage (3,84 mg/g) and higher than that in the hay crop (2,87 mg/g). The higher nitrogen level produced a aftergrowth crop containing significantly less calcium than did the lower nitrogen level (5,28—3,96 mg/g, 25 %). The higher potassium level also reduced the calcium content of the aftergrowth crop significantly (4,86—4,38 mg/g, 10 %).

The aftergrowth crop obtained from first year leys contained slightly more *potassium* (23,7 mg/g) than the corresponding crop from the second year leys (21,3 mg/g). Fertilizer applied in spring did not appear to affect the potassium content of the aftergrowth crop, since the higher potassium level increased it by a mere 6 % (21,9—23,1 mg/g).

The nutrient contents of the aftergrowth crop in this study were lower for the higher nitrogen level than for the lower nitrogen level. The largest differences in nutrient contents were seen in the crops from experiments 1 and 3, both of which contained clover. Clover had almost completely disappeared from those plots given the larger amount of nitrogen fertilizer.

The cation ratios (me) *K/Mg* (7,0) and *K/Ca + Mg)* (2,0) were smaller in the aftergrowth crop than in either the hay crop or the samples taken at the silage stage. The higher potassium level increased the value of both ratios significantly (K/Mg 6,2—7,8, 26 %; K/(Ca + Mg) 1,8—2,2, 22 %). Raising the amount of nitrogen fertilizer to the higher level also had the same effect (K/Mg 6,7—7,3, 9 %; K/(Ca + Mg) 1,9—2,1, 11 %). Magnesium fertilizer proved to produce a distinct decrease in the K/Mg ratio (8,3—5,7, 31 %) and it also reduced the K/(Ca + Mg) ratio by 10 % (2,1—1,9).

An increase in the soil magnesium content reduced the K/Mg ratio in the aftergrowth crop (r = —0,722**, b = —0,065). The K/Mg ratio in the soil caused a similarly marked increase in the ratio of these two nutrients in the aftergrowth crop ($r = 0,706^{**}$, $b = 1,937$). The cation ratio (K/Ca + Mg) in the aftergrowth crop fell as the soil magnesium content increased ($r = —0,558^{**}$, $b = —0,013$). Fluctuations in the soil potassium content did not change the value of either cation ratio in the aftergrowth crop.

A 1 mg/g increase in the calcium content of the aftergrowth crop reduced the K/(Ca + Mg) ratio by 0,262 ($r = —0,807^{**}$) and a similar increase in the magnesium content produced a drop of 0,741 ($r = —0,587^{**}$). On the other hand, a 1 mg/g increase in the potassium content raised the ratio by 0,134 ($r = 0,529^{**}$). The K/Mg ratio was more dependent on fluctuations in the magnesium content of the crop ($r = —0,802^{**}$, $b = —3,984$) than on fluctuations in the crop potassium content ($r = 0,245^{*}$, $b = 0,250$).

DISCUSSION

The application of magnesium fertilizer produced a significant increase in the magnesium content of samples of cereal shoots taken at the 4—5 leaf stage. However, it was not possible to determine the cereals' magnesium fertilizer requirement on the basis of the magnesium content of the shoots since the grain yield was not significantly dependent on the magnesium content of the shoots (JERLSTRÖM 1975, JOKINEN 1977 b).

The experimental treatments used produced small, but statistically significant, changes in the magnesium, potassium and calcium contents of the grain. In this respect the results obtained in field experiments are similar to those obtained in pot experiments (JOKINEN 1977 a).

Increasing the amount of nitrogen fertilizer resulted in a significant rise in the nitrogen content of the grain (SALONEN et al. 1962), producing crops with a high protein content. The other nutrient contents of the grain were not affected by increases in the nitrogen fertilizer (GASSER and THORBURN 1972).

In this study the dominant grassland species was timothy. The average magnesium contents of the hay crop and of samples taken at the silage stage were almost the same as those of samples taken from farmers' fields and from field experiments in a number of Finnish studies (LAKANEN 1969, JOKINEN 1969 a, RINNE et al. 1974, KÄHÄRI and NISSINEN 1978). Without magnesium fertilizer the magnesium content of the hay crop was sometimes as low as 0,45 mg/g. This is far below the limit of 1,0 mg/g MgO (0,66 mg/g Mg) set by KERÄNEN and TAINIO (1968) for magnesium deficiency in timothy. In a very small number of cases magnesium fertilizer increased the magnesium content of the crops to a value above the limit of 2 mg/g put forward by KEMP (1969) for livestock fodder. According to METSON et. al 1966) the magnesium content should be higher than this if the fodder has high potassium and nitrogen contents.

The magnesium content of crops harvested from grassland increased slightly as the exchangeable magnesium content of the soil increased (JOKINEN 1969 b, KÄHÄRI and NISSINEN 1978). Magnesium fertilizer produced a significant increase in the magnesium content of the crops at all the experimental sites in this study (BOLTON and PENNY 1968, JOKINEN 1971, CUNNINS and PERKINS 1974), although the yield from grassland crops increased in only a few experiments (cf. JOKINEN 1978). The increase in magnesium content of the yield produced by magnesium fertilizer was greatest at experimental sites where the soil magnesium content was lowest.

Doubling the amount of nitrogen fertilizer applied in the form of nitro-chalk produced a significant increase in the magnesium content of the crop both at the silage stage and in the hay (OLOFSSON 1964, ANDERSEN and SCHJELDERUP 1973). It was thus possible to improve the quality of the crops harvested from grassland by using both magnesium and nitrogen fertilizers (MAYLAND and GRUNES 1974).

Magnesium fertilizer also reduced the nutrient contents of the crops since there was a drop in calcium content in both the stand at the silage stage and in the hay crop. There was no change in the calcium content of the aftergrowth crop. The inhibition of magnesium on the uptake of calcium (SCHACHTSCHABEL and HOFFMANN 1958, MORGAN and JACKSON 1976) was seen more clearly on soil with a low calcium content than on the site where the soil was not in need of liming.

On many of the sites the soil potassium content increased during the first two years even with the lower potassium fertilizer level (60 kg/ha, cf. JOKINEN 1978) since the cereal crops took up only a small part of the potassium applied. The potassium content of the grassland crops in the years that followed was higher at this potassium fertilizer level than that found in other studies carried out in Finland (RAININKO 1968, JOKINEN 1969 a, RINNE et al. 1974, KÄHÄRI and NISSINEN 1978). A fourfold amount of potassium fertilizer significantly increased the potassium content of all grassland crops and at the same time the calcium and magnesium contents dropped (HÅLAND 1971, KLAUSEN and LARSEN 1977).

The annual application of magnesium sulphate fertilizer to an acid soil containing little calcium and magnesium increased the magnesium content of the crops. The plants are thus capable of utilizing magnesium from magnesium sulphate even on acid soil. A similar result was obtained by DRAYCOTT and DURRANT (1972) in their pot experiments with sugar beet.

The changes produced by the experimental treatments in the nutrient contents of cereal grain and straw and grassland crops were smaller than the fluctuations between sites. The weather during the growing season and the moisture content of the soil probably have an effect on the plants' nutrient contents (HEINONEN 1964, McNAUGHT et al. 1968, ABDEL RAHMAN et al. 1971).

Attempts have been made to predict the probability of grass tetany in cattle by means of the cation ratios K/Mg and K/(Ca + Mg) in the fodder. A limit of 6,0 has been given for the K/Mg ratio (JACOBSEN 1969) and of 2,2 for the K/(Ca + Mg) ratio (KEMP and t'HART 1957). In the present study the values of the ratios in the hay and in the samples taken at the silage stage exceeded the recommended limits even for the lower potassium fertilizer level. Increasing the potassium fertilizer fourfold produced a further, significant increase in the ratios. The changes in the ratios are probably due to the increase in the potassium content brought about by raising the amount of potassium fertilizer, as well as to the drop in magnesium and calcium contents. Increasing the amount of nitrogen fertilizer did not significantly change the values of the ratios (PANAK and HUMIECKI 1977). Doubling the amount of nitrogen fertilizer used may have raised the calcium content of the fodder due to the fertilizer's 20 % calcium content. The result obtained by RINNE et al. (1978) indicating that increasing the amount of nitrogen fertilizer did not affect the value of the K/(Ca + Mg) ratio may be due to the magnesium in the ammonium nitrate limestone.

The K/(Ca + Mg) ratio in the stand at the silage stage and in the aftergrowth crop was more highly dependent on fluctuations in the calcium content of the crop than on fluctuations in its magnesium content (MAYLAND et al. 1974). This may indicate that the value of this ratio can be kept low by seeing to it that the plants have a sufficient supply of calcium. The availability of both calcium and magnesium can be ensured for several years by using dolomitic limestone (McINTOSH et al. 1973). There was a close correlation between the potassium content and the cation ratio in the dry hay crop. According to HÅLAND (1971) fluctuations in the plant potassium content affect the cation ratio at an early stage of development.

The K/Mg ratio was highest in the stands at the silage stage and lowest in the aftergrowth crop. This may be due to the fact that the fertilizer was applied to the grasslands only at the start of the growing season. The K/Mg ratio of the crop was more dependent on fluctuations in the magnesium content of the crop than on fluctuations in its potassium content at all stages of development. Thus, the plants require a sufficient supply of magnesium to keep the K/Mg ratio low. The ratio can to some extent be affected by avoiding the application of large amounts of potassium fertilizer.

From the point of view of cattle fodder, the proportions of nutrients in the crop can be improved by increasing the proportion of clover in the stand (Baerug 1977, Klausen and Larsen 1977). The calcium and magnesium contents of clover are many times higher than in grass species (Jokinen 1969 a, Baerug 1977). The potassium content of these two plant groups deviate little (Raininko 1968, Jokinen 1969 a). The competition for potassium between clover and grass species in mixed stands keeps the potassium content of clover in the dry hay crop low, providing the proportion of clover in the stand is not high (Jokinen 1969 a). Application of large amounts of nitrogen fertilizer to leys containing clover reduces the proportion of clover in the crop, at the same time reducing the calcium and magnesium contents of the crop (Klaussen and Larsen 1977, Raininko 1968).

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SELOSTUS

Magnesium-, kalium- ja typpilannoituksen vaikutus kevätviljojen ja nurmen satojen ravinnepitoisuuksiin sekä -suhteisiin

Raili Jokinen

Maatalouden tutkimuskeskus

Seitsemässä Maatalouden tutkimuskeskuksen koeasemilla suoritetussa kenttäkokeessa tutkittiin magnesiumsulfaattilannoituksen (57 kg/ha Mg) vaikutusta viljojen ja nurmien satojen ravinnepitoisuuksiin kahdella kaliumkloridi- (K_1 = 60, K_4 = 240 kg/ha K) ja kahdella kalkkisalpietarilannoituksen (N_1 = 50, N_2 = 100 kg/ha N) tasolla. Viisi vuotta jatkuneissa kokeissa lannoitukset annettiin vuosittain keväällä sekä viljoille että nurmille. Nurmista punnittiin heinä- ja odelmasato, viljoista jyväsato.

Magnesiumlannoitus tai kalium- ja typpilannoituksen lisäys eivät muuttaneet jyvien kalium- tai kalsiumpitoisuutta merkitsevästi. Magnesiumpitoisuus kohosi magnesiumlannoituksella 4 % (1,11—1,16 mg/g). Kalium- tai typpilannoitus eivät aiheuttaneet muutoksia magnesiumlannoituksella saatuun tulokseen. Jyvien typpipitoisuus kohosi merkitsevästi typpilannoitusta lisättäessä.

Tutkittujen lannoitusten vaikutukset viljan olkien ravinnepitoisuuksiin olivat samansuuntaiset kuin nurmen satojen ravinnepitoisuuksiinkin.

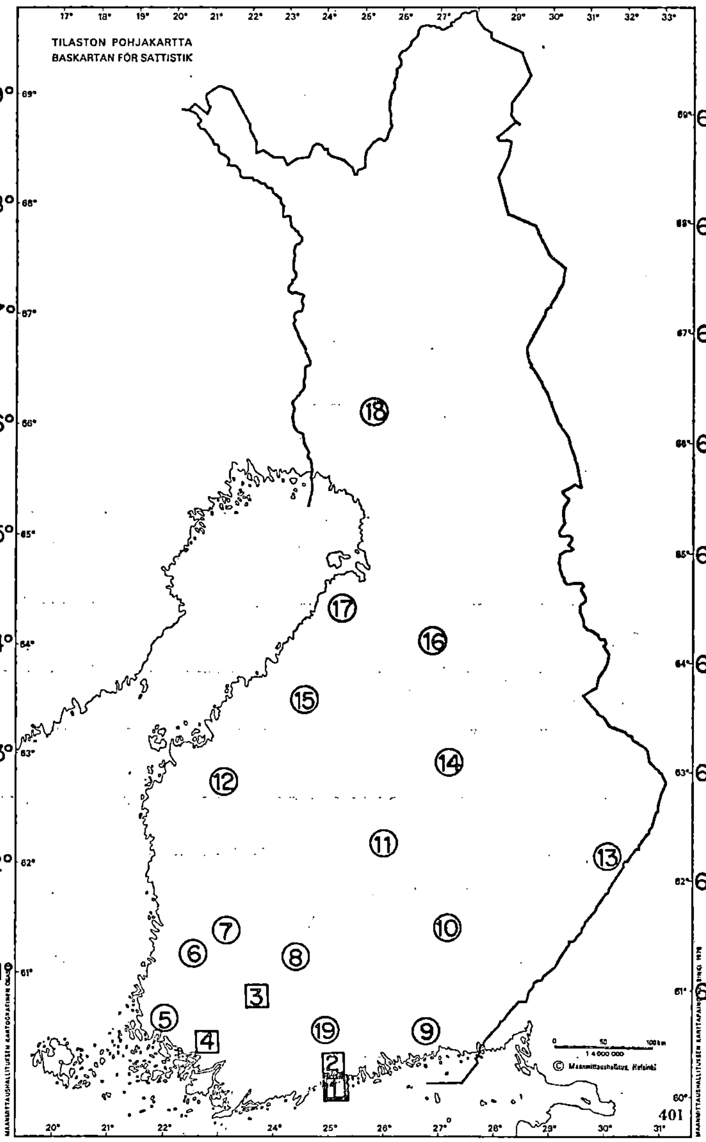
Nurmien pääasiallisin kasvi oli timotei. Sadon ravinnepitoisuudet määritettiin koko kasvustoa edustavista näytteistä. Nurmien kasvustosta otettiin näytteet säilörehuasteella (ei sadonkorjuuta) sekä kuivaksi heinäksi korjatusta sadosta ja odelmasadosta.

Magnesiumlannoitus kohotti merkitsevästi säilörehuasteella kasvuston magnesiumpitoisuutta (1,11—1,61 mg/g, 44 %) ja pienensi sekä kalsiumpitoisuutta (4,11—3,37 mg/g, 18 %) että suhdetta K/Mg (11,9—8,4, 29 %). Nelinkertaisen kaliumlannoituksen aiheuttama kaliumpitoisuuden (39,7—42,2 mg/g, 7 %), suhteiden K/Mg (9,2—11,1, 20 %) ja K/(Ca + Mg) (3,3—3,9, 18 %) nousu samoin kuin kalsiumpitoisuuden aleneminen (3,99—3,68 mg/g, 8 %) olivat merkitsevät. Typpilannoituksen lisääminen kaksinkertaiseksi kohotti säilörehuasteen kalium- (38,5—43,6 mg/g, 13 %) ja kalsiumpitoisuutta (3,54—4,14 mg/g, 17 %) merkitsevästi samalla suhde K/(Ca + Mg) pieneni 5 % (3,7—3,5). Maan magnesiumpitoisuuden (happamaan ammoniumasetaattiin uuttuva) noustessa sadon magnesiumpitoisuus kohosi (r = 0,407**).

Heinäsadon magnesiumpitoisuus kohosi magnesiumlannoituksella 34 % (0,80—1,07 mg/g) ja kalsiumpitoisuus (3,06—2,68 mg/g, 12 %) samoin kuin suhde K/Mg (11,0—8,0, 27 %) pienenivät. Kaliumlannoituksen lisäys nelinkertaiseksi kohotti heinän kaliumpitoisuutta 14 % (25,7—29,2 mg/g), suhdetta K/Mg 25 % (8,4—10,5) ja suhdetta K/Ca + Mg) 23 % (2,9—3,6), mutta vähensi magnesiumpitoisuutta 9 % (0,98—0,89 mg/g) ja kalsiumpitoisuutta 5 % (2,94—2,80 mg/g). Kaksinkertaisen typpilannoituksen aiheuttama magnesium- (0,89—0,98 mg/g, 10 %), kalium- (26,3— 28,6 mg/g, 9 %), kalsium- (2,71—3,03 mg/g, 11 %) ja typpipitoisuuden (14,7—17,8 mg/g, 21 %) nousu oli merkitsevä. Maan magnesiumpitoisuuden ja heinän magnesiumpitoisuuden välillä vallitsi positiivinen vuorosuhde (r = 0,649**).

Keväällä annetulla magnesiumlannoituksella oli positiivinen vaikutus odelmasadon magnesiumpitoisuuteen (1,00—1,37 mg/g, 37 %). Suhde K/Mg pieneni 31 % (8,3—5,7) ja suhde K/(Ca + Mg) 10 % (2,1—1,9). Kaliummäärän lisääminen nelinkertaiseksi pienensi kalsiumpitoisuutta 10 % (4,86—4,38 mg/g) sekä kohotti K/Mg 26 % (6,2—7,8) ja K/(Ca + Mg) 22 % (1,8—2,2). Suurella typpilannoitemäärällä tuotetut sadot sisälsivät 16 % vähemmän magnesiumia (1,28—1,08 mg/g) ja 25 % vähemmän kalsiumia (5,28—3,96 mg/g) kuin pienellä typpimäärällä saadut odelmasadot. Suhde K/Mg nousi 9 % (6,7—7,3) ja K/(Ca + Mg) 11 % (1,9—2,1). Maan magnesiumpitoisuuden noustessa odelmasadon magnesiumpitoisuus kohosi (r = 0,425**), suhteet K/Mg (r = —0,722**) ja K/(Ca + Mg) (= —0,588**) pienenivät.

Säilörehuasteen ja odelmasadon sisältämien kaliumin ja magnesiumin suhteen muutokset riippuivat voimakkaammin sadon magnesiumpitoisuuden kuin kaliumpitoisuuden vaihteluista. Heinäsadossa suhteen arvoon vaikuttivat sadon kyseisten ravinteiden pitoisuudet yhtä voimakkaasti. Suhde K/(Ca + Mg) muuttui selvimmin edulliseen suuntaan säilörehuasteella ja odelmasadossa, kun sadon kalsiumpitoisuus nousi. Kalkituksella voitaneen parantaa Suomen happamilta mailta saatavien nurmisatojen laatua. Heinäsadossa kaliumpitoisuuden vaikutus suhteeseen K/(Ca + Mg) oli muita ravinnepitoisuuksia voimakkaampi.



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