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Seria HORTICULTURA N. 25 — Sarja PUUTARHAVILJELY n:o 25

THE EFFECT OF PROPAGATION TIME AND SEED POT VOLUME ON THE YIELD OF GREENHOUSE LETTUCE IN DIFFERENT GROWING SEASONS

LEA KURKI

KURKI, L. 1974. **The effect of propagation time and seed pot volume on the yield of greenhouse lettuce in different growing seasons.** Ann. Agric. Fenn. 13: 71—78.

Effects of the length of propagation period and of various types and sizes of seed pot on the marketable yield of greenhouse lettuce under growing conditions prevailing at 60° N, 23° E were studied during 1970—72. Customary 35—125 cm^3 pots gave a satisfactory commercial result; variation in pot size within these limits did not produce large differences in yield although yields were found to increase slightly with increased potvolume. Yield differences due to pot volume are gratest under poor growing conditions; when yields can be increased markedly by increasing the pot size. Under favourable conditions pot size is less important. A pressed peat block of 125 cm^3 proved the best growing substrate for lettuce plants and gave yields just as great as those obtained from the largest seed pots. Extending the length of propagation period increases yield in those seasons when propagation conditions are better than conditions during the actual growing period, providing that larger pots are used for the longer periods. In cases when conditions were equally favourable during both periods, 14 to 18 days proved a suitable period for propagation in greenhouses. In the autumn, when growing conditions deteriorate as the light decreases, yields drop if propagation periods longer than 14 days are applied.

The propagation methods in lettuce growing have changed rapidly in recent times. In stead of broadcast sowing and pricking out seedlings, plants are now raised in propagation containers. Types of containers commonly in use are plastic, peat, or paperpots-, and pressed blocks of peat or soil. The customary pot size is 4—5 cm, both in height and diameter (HOEVEN and BARENDSE 1967, ANON. 1969). Seeds are sown directly in the pots which are later placed in the final growing positions. Abandoning of the pricking-out phase has resulted in faster development and has increased yields (HOEVEN and BARENDSE 1967, LINDFORS 1969, ANDRESEN and FRENZ 1972).

The lettuce seedlings are raised in greenhouses. Growth rooms suitable for this purpose (CANHAM 1971, DULLFORCE 1971) are seldom used. Growing conditions in greenhouses vary according to the time of the year especially in terms of light (Table 1) and day length. They are reflected in production costs in the form of additional light and heating. The growth requirements of lettuce during the periods of propagation and growth on the final site have been described in considerable detail in professional literature. No attention has been paid, however, to the possible effects of seed pot size and length of propagation period on the development of lettuce under the different grow-

Table 1. Total radiation at 60° 23′ N, 22° 33′ E (Piikkiö, Finland).

Month	Mean total radiation outside in 1968—1971 cal/cm^2	Total radiation in greenhouses approx. cal/cm^2
January	773	352
February	2 289	1 033
March	5 825	4 020
April	9 290	7 885
May	12 924	8 598
June	16 722	8 873
July	14 582	5 933
August	12 011	1 800
September	6 279	600
October	2 989	200
November	945	not measured
December	472	» »

ing conditions of the different seasons. Propagation experiments were therefore conducted at the Institute of Horticulture during 1970—72 to investigate the effect of different types and sizes of pots and of the length of propagation period on the yield of greenhouse lettuce during different growing seasons.

Materials and methods

The variety 'Noran' (Rijk Zwaan, Holland) was used for the propagation experiments; for the comparison of varietal response to different seed pots the varieties 'Deci-Minor' and 'Larganda' (Rijk Zwaan, Holland) and 'Sally' (Hammenhög, Sweden) were added. The seedlings were grown in greenhouses in which the seasonal growing conditions were regulated as shown in Table 2. Total light level in the greenhouses is shown in Table 1. Artificial light was given between Jan. 4 and Feb. 15 twelve hours daily, from 08.00 to 20.00. The light was from Floralux 80 W lamps and illumination intensity at the level of the seedlings approximately 3 000 lux. Details of the seed pots used are given in Table 3. Growing seasons and dates of sowing, transplanting and harvest together with the experimental results are shown in Tables 4 and 5.

Light *Sphagnum* peat with a decomposition degree of 2—3 was used to fill the pots and to prepare the pressed peat blocks. For lettuce propagation the peat was dressed with 12 kg/m^3 of dolomite lime (CaO 52 %, Ca 35 %, Mg approx. 10 %) and 1.2 kg/m^3 of compound Super Y Fertilizer for Peat ($N—P_2O_5—K_2O$ 8—30—18 plus trace elements). The soil blocks used were prepared from a mixture of 50 % of the abovementioned peat, 25 % leaf mould, 20 % clay, and 5 % sand, dressed with 1.2 kg/m^3 of the above Super Y Fertilizer for Peat.

Growing conditions during the period in the greenhouse after transplanting (referred to as 'growing period') are shown in Table 2. Growth density during propagation was that of the pots (Table 3) and in the growing period 20 × 20 cm or 25 plants per m^2. Entire experiments were harvested at the same time. In all experiments a trial plot consisted of ten plants and there were five replications.

Results

Table 4 presents data on the effect of the most commonly used propagation pots on the marketable yield of greenhouse lettuce. Despite quite a large variation in pot volume (Table 3), relatively small differences in yield were obtained with the different pots. The yield is seen to increase with increasing pot volume but this was only significant with the peat blocks in the winter and autumn seasons.

Table 2. Greenhouse conditions for lettuce propagation and for lettuce growing during different growing seasons.

Temperature °C	Winter		Spring		Summer		Autumn	
	Prop.	Grow.	Prop.	Grow.	Prop.	Grow.	Prop.	Grow.
air, day	18	15—18	20	18—22	20	18—22	20	15—17
air, night	15	13—15	17	13—15	17	15—17	17	13—15
soil	18	18	18	18	20	20	20	18
CO_2 ppm	0.08	0.08	0.08	0.03	0.03	0.03	0.08	0.08
relative humidity %	70	70	70	70	70	70	70	70

Table 3. Propagation containers used in experiments.

Type of pot	diameter cm	height cm	volume cm^3	pots/m^2
peatpot FP 715	4.0	4.0	35.0	420
plastic net pot 4 × 4 cm	4.0	4.0	35.0	600
paperpot Bh 408/2	3.8	3.7	35.2	1 066
„ Vh 505	5.0	5.0	81.2	616
„ Vh 605	6.0	5.0	116.2	428
„ Vh 808	7.5	7.5	274.0	274
„ Vh 1 010	10.0	10.0	649.5	154
peat block, hand pressed	5.0	5.0	125.0	400
soil block, hand pressed	5.0	5.0	125.0	400

Table 4. The effect of the most used propagation pots on the marketable yield of greenhouse lettuce in different growing seasons.

Propagation pot	Marketable yield kg/m^2			
	winter	spring	summer	autumn
paperpot Bh 408/2	2.9	4.0	4.2	2.8
„ Vh 505	3.1	4.3	4.7	3.0
„ Vh 605	3.6	4.6	5.0	3.2
peatpot FP 715	3.0	4.3	4.2	3.2
peat block hand pressed	3.8***	4.8	5.1	3.6**
plastic net pot	3.0	4.3	4.5	3.3
mean	3.2	4.4	4.3	4.2
F	93.2***	8.2*	23.1**	27.4**
sign.diff. kg/m^2	0.7	1.5	0.6	0.5
sown	Jan. 3	March 16	June 7	Aug. 23
transplanted	Jan. 24	April 2	June 23	Sept. 9
harvested	March 23	May 3	July 19	Nov. 4

The effect of seed pots on the marketable yield of greenhouse lettuce in different growing seasons and following different sowing dates is shown in Table 5. The yields are given in ratios. For each sowing time the control treatment consisted of plants grown in paperpots Vh 505 with a volume of 81.2 cm^3. The general observation is that yields increase with increasing pot volume. With almost every sowing time included in the experiment a significantly larger yield was obtained from plants raised in paperpot Vh 808, vol. 274 cm^3, in paperpot Vh 1010, vol. 649.5 cm^3, and in the 5 × 5 × 5 cm peat block with a volume of 125 cm^3. From paperpot Bh 408/2 and peatpot FP 715, equal in volume (35 cm^3), yields were significantly lower than from the controls following most of the sowing dates.

Results with summer lettuce in the spring season (Table 5) show that if light (Table 1) and other conditions (Table 2) are favourable during propagation as well as during the growing period, the effect of the pot diminishes. In the autumn, on the other hand, when conditions during the growing period deteriorate especially in terms of light (Table 1), the lettuce yield increases with increased pot as it does with favourable qualities in the growth substrate, represented in these experiments by the pressed peat block. The results with autumn lettuce also show that if sowing is postponed beyond the very first days of September, there is no chance of obtaining satisfactory yields of lettuce even in the southernmost parts of Finland.

Fig. 1 illustrates the effect of the length of propagation period on the marketable yield of greenhouse lettuce during different growing seasons when plants are grown in pots of different volumes. Extending the propagation period from 14 to 18 days increases the yields from all pots when sown in January, February or March. A propagation period shorter than this reduces the yields from the smallest pot included, Vh 505, 81.2 cm^3, when sown in early January, and the yields from pots of all sizes when sown in February or March. With seed

Table 5. The effect of seed po and sowing time on the marketable yield of greenhouse lettuce in different growing seasons.

Season; sowing, transplanting harvesting dates	Relative marketable yield seed pots:								
	B h408/2	Vh 505	ratio kg/m²	Vh 605	Vh 808	Vh 1 010	peat block	soil block	FP 715
winter									
Jan 5, 26, March 26	87***	100	3.2	110	119***	129***	122***	92	82***
Febr. 5, 26, April 15	89	100	4.0	102	102	114***	104	96	86
spring									
March 16, 30, May 5	91	100	4.8	107*	105*	112*	112*	99	101
April 20, May 4, June 1 ..	91**	100	4.8	110**	110**	111**	107**	100	87**
summer									
May 20, June 5, 30	92	100	4.8	105	109***	112***	107***	100	93
June 15, 30, July 30	96	100	4.9	106	107	110***	106	100	96
July 1, 14, Aug. 30........	97	100	5.0	103	108***	111***	112***	97	98
autum									
July 31, Aug. 14, Sept. 20..	65***	100	4.9	106	107***	109***	108***	92	70***
Aug. 16, 31, Oct. 24	70***	100	3.5	105	106***	110***	110***	92	87***
Aug. 25, Sept. 10, Oct. 30 ..	67***	100	3.4	109	111***	112***	109	99	78***
Sept. 2, 23, Nov. 10	77***	100	2.0	106	110***	119***	110***	101	79***
Sept. 13, Oct. 1, Nov. 10 ..	67***	100	1.3	104	118***	117***	116***	98	80***

*** = 99.9 % significance
** = 99 % significance
* = 95 % significance
Propagation time 21 days in winter, 14 days in other seasons

pot volumes exceeding 81.2 cm³, yields remain constant if the propagation period for crops sown in early January is increased beyond 18 days. A slight rise in yield is observed with all pot sizes when extended propagation periods are applied to plants sown in late January. Within the range of pot sizes included in these experiments, it seems apparent that for crops sown late in the winter 18 days is the optimum length for propagation time. In the autumn, yields begin to decline with propagation periods longer than 14 days. Fourteen days was indeed the shortest period applied, so it is not known what the effects of even shorter periods might have been on autumngrown lettuce.

Discussion

Vigorous lettuce seedlings can be produced by various methods. Different types (Table 4) and volumes of seed pots (Table 3), and the peat block, commonly in use e.g. in Holland (Hoeven and Slobbe 1967), East Germany (Urban 1967), West Germany (Hösslin and Andresen 1968), Sweden (Lindfors 1969, 1970) and Great Britain (Large 1972), have given satisfactory results in Finland. Development appears to be promoted if lettuce seedlings are grown in pots with a diameter equal to or slightly larger than the pot height (Kurki 1970) due to the growth habit of their root system (Post and Groenewegen 1960). The main drawback with too small pots is the danger of abrupt changes in moisture conditions (Urban 1967). This factor was not very apparent in the present experiments and affected the results very little, as detrimental changes in moisture were avoided successfully.

The suitability of a seed pot for production of lettuce seedlings depends, of course, also on the quality of the filling material. The choice of peat as the filling material for the pots as well as for the peat blocks used in these experiments was based on the peat quality studies by Puustjärvi (1967). The superiority of peat over a soil mixture is clearly seen from Table 5. The peat block constituted an excellent growth

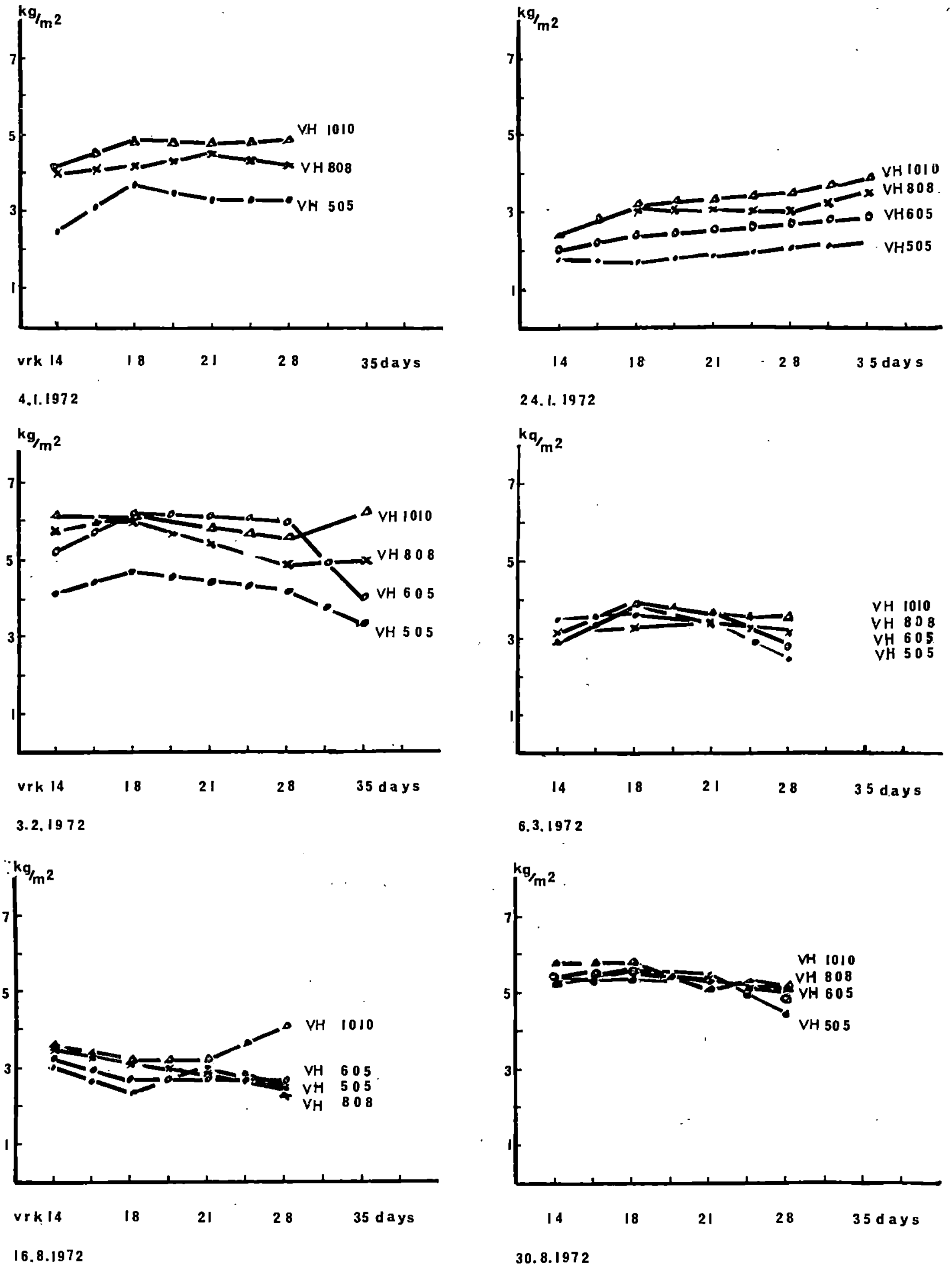

Fig. 1. The effect of the lenght of the propagation time and the volume of the seed pots on the marketable yield of lettuce at different growing seasons.
Lettuce varieties: 'Deci-Minor RZ' on the sowing dates January 4. and 24., February 2., 'Noran RZ' March 3. and August 8. 1972.

Kuva 1. Taimikasvatusajan pituuden ja kylvöruukun tilavuuden vaikutus salaatin kauppakelpoiseen satoon eri viljelykausina. Salaattilajikkeet: 'Deci-Minor RZ' kylvetty 4. ja 24. 1., 3. 2. ja 30. 8. 'Noran RZ' 6. 3. ja 16. 8. 1972.

substrate for lettuce in all seasons (Table 5). URBAN (1967) has further found that machine pressed peat blocks can produce heavier yields than hand pressed blocks.

The effect of seed pot size on the yield of lettuce also depends on the conditions during propagation and growth. As far north as Finland artificial light is essential for growing lettuce seedlings in winter. Favourable conditions will thus be arranged for the propagation period (see Table 5, Jan. 5 sowing), but in the ensuing growing period lack of light (Table 1) constitutes a severe growth-limiting factor. Under such conditions increasing the size of the seed pot appears to improve the yield much more than it does when both propagation and growth conditions are less favourable, with regard to light (Table 1) as was the case with our early February sowing (Table 5). Likewise, the effect of pot size is less important under optimal propagation and growing conditions i.e. in spring and summer (Table 5). With autumn lettuce the yield differentials, generally in favour of the larger pots, are seen to increase as conditions during the growing period. deteriorate; in our experiments this occurred when natural light declined (Table 1).

It is advisable to extend the propagation period (Fig. 1) when conditions are more favourable during propagation than during the actual growing period. This presupposes, however, the use of larger pots along with extended propagation periods. According to a recent study (BIERHUIZEN et al. 1973) the development of lettuce plants consists of three phases: ger-f mination; growth until foliage covers 100 % o the ground (rosette stage with leaves 7—10 cm); growth hence until harvest. Development in the middle phase, which includes the propagation period, depends mainly on the sum of effective temperature and in the third phase on the amount of light. Thus, lengthening the propagation period during the cold winter season will result in savings in heating costs, since much less space is needed for propagation than for growth on the actual growing site.

REFERENCES

ANON. 1969. Sla onder glas. Com. voor sla v.d. Nederlandse Federative van Tuinbouwstudiegr. e.h. Consulentsh., Naaldwijk, 22 p.

ANDRESEN, F. & FRENZ, F.-W. 1972. Dierktsaat voor Kopfsalat in verschiedene Topfarten. Der Erwerbsgärtner 7: 262—265.

BIERHUIZEN, J. F., EBBENS, J. L. & KOOMEN, N. C. A. 1973. Effects on temperature and radiation on lettuce growing. Neth. J. Agric. Sci. 21: 110—116.

CANHAM, A. E. 1971. The growing room in commercial horticulture. Acta Hortic. Tech. Comm. ISHS 22: 156—163.

DULLFORCE, W. M. 1971. The growth of winter glasshouse lettuce with artificial light. Acta Hortic. Tech. Comm. ISHS 22: 199—210.

HOEVEN, A. P. v.d. 1969. Lettuce I. Raising young plants. Ann. Rep. 1967 & 1968 Glasshouse Crops Res. Sta. Naaldwijk, Netherlands pp. 48—49.

— & BARENDSE, V. 1967. Nieuwe opkweekmethoden van sla. Jaarversl. 1966 Proefst. voor de Groente — en Fruiteelt onder Glaas te Naaldwijk: 73—77.

— & SLOBBE, A. 1967. Opkweekmethode "Zadjepotje" bij sla. Groenten en Fruit 23, 13: 575.

HÖSSLIN, A. v. & ANDRESEN, F. 1968. Paperpots zur Anzucht von Gemüse — Jungpflanzen. Gemüse 4 (12): 295—296.

KURKI, L. 1970. Propagation pots and planting depths in autumn and winter lettuce growing. Paperpot Family News 1: 9—10.

LARGE, J. C. 1972. Glasshouse lettuce. 181 p. London.

LINDFORS, S. 1969. Försök med jordkrukor vid uppdragning av sallatsplantor i växthus 1967—1968. Viola-Trädgårdsv. 75, 2: 7.

— 1970. Försök vid Alnarp med jordkrukor vid uppdragning av salladsplantor. Viola-Trädgårdsv. 76, 9: 8—9.

POST, C. J. v.d. & GROENEWEGEN, C. L. 1960. Wortelontwikkeling van Sla. Meded Dir. Tuinb. 23, 1: 107—117.

PUUSTJÄRVI, V. 1968. What an ideal growing medium is like. Peat and Plant News 1, 2: 27—29.

URBAN, L. 1967. Vergleich von Gemüse- erträgen bei der Anzucht in Erdpresswurfeln und anderen Töpfen. Die Gartenbauw. 32, 14: 321—329.

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SELOSTUS

Taimikasvatusajan ja kylvöruukun tilavuuden vaikutus kasvihuonesalaatin satoon eri viljelykausina

LEA KURKI

Maatalouden tutkimuskeskus

Salaatin taimikasvatusmenetelmät ovat lyhyessä ajassa muuttuneet. Hajakylvön ja koulimisen asemesta on ryhdytty käyttämään kylvöruukkuja. Yleisimmät ruukkutyypit salaatin taimikasvatuksessa ovat tällä hetkellä muovi-, turve- ja paperiruukut sekä puristetut turve- tai multakuutiot. Ruukun suuruudeksi on vakiintunut korkeudeltaan ja halkaisijaltaan 4—5 cm:n koko (HOEVEN ja BARENDSE 1967, ANON. 1969). Siemen kylvetään suoraan ruukkuun, jossa taimi istutetaan lopulliselle kasvupaikalleen. Luopuminen taimien koulimisesta on nopeuttanut salaatin kehitystä ja lisännyt satoa (HOEVEN ja BARENDSE 1967, LINDFORS 1969, ANDRESEN ja FRENZ 1972).

Salaatin taimet kasvatetaan kasvihuoneissa. Tähän tarkoitukseen soveltuvia kasvatushuoneita (CANHAM 1971, DULLFORCE 1971) käytetään toistaiseksi sangen vähän. Kasvuolosuhteet vaihtelevat vuodenajoittain kasvihuoneissa erityisesti säteilyn määrän (taul. 1) ja päivän pituuden suhteen. Näiden vaikutus heijastuu tuotantokustannuksiin esimerkiksi lisävalon ja lämmityksen kohdalla. Salaatin kasvuvaatimuksia taimi- ja jatkokasvatuksen aikana selostetaan melko yksityiskohtaisesti ammattikirjallisuudessa. Ei ole kuitenkaan kiinnitetty huomiota siihen, miten kylvöruukun tilavuus ja taimikasvatusajan pituus vaikuttavat salaatin kehitykseen eri vuodenaikojen kasvuoloissa. Tämän vuoksi vuosina 1970—1972 suoritetuissa kasvihuonesalaatin taimikasvatuskokeissa Puutarhantutkimuslaitoksella selvitettiin eri tyyppisten ja tilavuudeltaan erilaisten kylvöruukkujen sekä taimikasvatusajan pituuden vaikutusta kasvihuonesalaatin satoon eri vuodenaikoina.

Aineisto ja menetelmät

Taimikasvatuskokeet suoritettiin lajikkeella 'Noran' (Rijk Zwaan, Hollanti) ja verrattaessa lajikkeiden suhtautumista erilaisiin kylvöruukkuihin lisäksi lajikkeilla 'Deci-Minor' ja 'Larganda' (Rijk Zwaan, Hollanti) sekä 'Sally' (Hammenhög, Ruotsi). Taimet kasvatettiin kasvihuoneissa, joiden olosuhteet säädettiin viljelykausittain siten kuin taulukossa 2 esitetään. Kokonaissäteilyn taso kasvihuoneissa on nähtävissä taulukosta 1. Lisävaloa annettiin tammikuun 4. ja helmikuun 15. päivän välisenä aikana päivittäin 12 t klo 08.00—20.00 Floralux 80 W lampuilla siten, että valoisuus taimien tasolla oli noin 3 000 luxia. Kokeissa käytettyjen taimiruukkujen ominaisuudet ilmenevät taulukosta 3. Viljelykaudet, kylvö-, istutus- ja korjuuajat esitetään kokeiden tulostaulukoiden yhteydessä.

Kylvöruukkujen täyttöaineena ja puristettujen turvekuutioiden valmistukseen käytettiin vaaleata Sphagnumturvetta, jonka maatumisaste oli 2—3. Se lannoitettiin taimikasvatusta varten seuraavasti: 12 kg/m^3 dolomiittikalkkia (CaO 52 %, Ca 35 %, Mg n. 10 %) sekä Turpeen Super Y-lannoksella 1.2 kg/m^3 (N — P_2O_5 — K_2O 8 — 30 — 18 sekä hivenaineet). Multakuutiot valmistettiin seoksesta: 50 % edellä mainittua turvetta, 25 % lehtimultaa, 20 % savea ja 5 % hiekkaa, ja lannoitettiin edellä esitetyllä Turpeen Super Y-lannoksella 1.2 kg/m^3.

Jatkokasvatusolosuhteet kasvihuoneessa on esitetty taulukossa 2. Kasvutiheys taimikasvatusaikana oli sama kuin ruukkujen tiheys (taul. 3) ja jatkokasvatuksen aikana 20 × 20 cm eli 25 tainta/m^2. Sato korjattiin kokeittain yhdellä kertaa. Koeruutu käsitti kaikissa kokeissa 10 yksilöä ja kerranteita oli viisi.

Tulokset

Nykyisin eniten käytettyjen kasvihuonesalaatin kylvöruukkujen vaikutusta kauppakelpoiseen satoon esitetään taulukossa 4. Huolimatta tilavuuden verrattain suuresta vaihtelusta (taul. 3) satoerot ovat eri kylvöruukuissa tuotetuilla salaateilla suhteellisen pienet. Sadon määrä kyllä suurenee ruukkujen tilavuuden kasvaessa, mutta merkitsevästi ainoastaan turvekuutioissa talvi- ja syyskausina.

Kylvöruukkujen vaikutus kasvihuonesalaatin kauppakelpoiseen satoon viljelykausittain eri kylvöaikoina on nähtävissä taulukosta 5. Sadot esitetään suhdelukuina. Verranteena on jokaisena kylvöaikana erikseen se sato, joka on saatu paperpot Vh 505 -kylvöruukuissa (tilavuus 81.2 cm^3) kasvatetuilla taimilla. Yleisesti on havaittavissa, että sato paranee kylvöruukun suuretessa. Merkitsevästi suurempi sato saadaan lähes kaikkina kokeeseen sisältyvinä kylvöaikoina niillä salaatin taimilla, jotka on kasvatettu paperpot Vh 808, tilavuudeltaan 274 cm^3 ja paperpot Vh 1010, tilavuudeltaan 649.5 cm^3 sekä 5 × 5 × 5 cm:n turvekuutiolla, jonka tilavuus on 125 cm^3. Tilavuudeltaan samankokoiset kylvöruukut paperpot Bh 408/2 ja FP 715 (35 cm^3) tuottavat lähes kaikkina kylvöaikoina merkitsevästi pienemmän sadon kuin verranteena ollut koejäsen.

Kevätkauden kesäsalaatin satotuloksista samassa taulukossa on havaittavissa, että kun taimi- ja jatkokasvatusolosuhteet ovat suotuisat valon (taul. 1) ja muiden kasvuolosuhteiden (taul. 2) puolesta, vähenee kylvöruukun vaikutus. Syksyllä sen sijaan, kun jatkokasvatusolosuhteet huononevat erityisesti valon kohdalla (taul. 1), suurenee salaatin sato kylvöruukun myötä sekä kasvualustan ollessa muuten suotuisan, jollainen tulosten perusteella on kokeissa mukana oleva puristettu turvekuutio. Syyssalaatin satotuloksista eri kylvöaikoina on myös havaittavissa, että elo-syyskuun vaihdetta myöhemmiksi siirtyvät kylvökset eivät tuota tyydyttävää satoa Suomen eteläisimmissäkään osissa.

Taimikasvatusajan pituuden vaikutusta eri viljelykausina kasvihuonesalaatin kauppakelpoiseen satoon silloin kun taimet on kasvatettu tilavuudeltaan erilaisissa kylvöruukuissa esitetään kuvassa 2. Taimikasvatusajan pidentäminen 14 vrk:sta 18 vrk:een lisää satoa kaikilla kokeissa mukana olleilla kylvöruukkutilavuuksilla tammi-, helmi- ja maaliskuun kylvöksillä. Tätä pienempi taimikasvatusaika vähentää satoa pienimmällä kokeessa olleella kylvöruukulla Vh 505, tilavuus 81.2 cm^3, tammikuun alkupuolen kylvöksellä, ja kaikilla kylvöruukkutilavuuksilla, kun kylvöaika on helmi-maaliskuussa. Kylvöruukun tilavuuden ollessa suurempi kuin edellä mainittu pysyy sato saman suuruisena kylvöajan pidetessä yli 18 vrk:n tammikuun alussa kylvetyllä taimierällä. Tammikuun lopussa kylvetyillä taimilla aiheuttaa taimikasvatusajan pidentäminen vähäistä nousua satomäärissä kaikkien ruukkutilavuuksien kohdalla. Kevättalven kylvöksillä näyttää 18 vrk olevan suotuisin taimikasvatusaika kokeessa olleilla kylvöruukkutilavuuksilla, ja syksyllä sato alkaa laskea 14 vrk:n taimikasvatusajan jälkeen. Neljätoista vuorokautta oli lyhin kokeessa ollut taimikasvatusaika, joten tässä yhteydessä ei ole selvitetty vieläkin lyhyempien taimikasvatusvaiheiden vaikutusta satoon syysviljelyssä.

Tulosten tarkastelu

Hyvän kasvutarmon omaavia salaatin taimia voidaan tuottaa monella tavalla. Erilaiset kylvöruukkutyypit (taul. 4), tilavuudet (taul. 3) sekä turvepaakku, joita käytetään esimerkiksi Hollannissa (HOEVEN, SLOBBE 1967), Itä-Saksassa (URBAN 1967), Länsi-Saksassa (HÖSSLIN ja ANDRESEN 1968), Ruotsissa (LINDFORS 1969, 1970) ja Englannissa (LARGE 1972), ovat antaneet tyydyttävän tuloksen myös Suomessa. Salaatin taimien kehitykselle näyttää olevan edullista, että ruukun halkaisija on yhtä suuri tai suurempi kuin korkeus (KURKI 1970), mikä johtuu salaatin juuriston kasvutavasta (POST ja GROENEWEGEN 1960). Kylvöruukun pienuudesta aiheutuva suurin haitta on ensisijaisesti niissä tapahtuva kosteuden äkkinäinen vaihtelu (URBAN 1967). Se, että tällä ei ollut tutkimuksessa suurempaa vaikutusta satoon kuin tulokset osoittavat, johtunee osaltaan siitä, että kasvualustan kosteuspitoisuudessa ei päässyt muodostumaan haitallisia muutoksia.

Kylvöruukun kelpoisuus taimikasvatukseen riippuu tietysti ratkaisevasti myös täyttöaineen laadusta. Kasvuturpeen valinta käsillä olevassa tutkimuksessa ruukkujen täyttöaineeksi ja turvekuution valmistusaineeksi perustuu PUUSTJÄRVEN (1967) tutkimuksiin kasvuturpeen ominaisuuksista. Kasvuturpeen paremmuus esimerkiksi multaseokseen nähden ilmenee taulukosta 5. Turvekuutio muodostikin erityisen suotuisan kasvualustan salaatin taimille kaikkina vuodenaikoina (taul. 5). URBAN (1967) on lisäksi todennut, että koneellisesti puristetuissa turvekuutioissa kasvatetut salaatin taimet tuottavat painavamman sadon kuin käsivoimalla puristetut kuutiot.

Eri kokoisten kylvöruukkujen vaikutus salaatin satoon on myös taimi- ja jatkokasvatusolosuhteiden määräämää. Talvella salaatin taimikasvatus on maamme leveysasteilla mahdollista vain lisävalon turvin. Tällöin (taul. 5, kylvö tammik. 5.) taimikasvatusolosuhteet järjestetään suotuisiksi, mutta jatkokasvatusaikana on erityisesti valo (taul. 1) kasvua jarruttava tekijä. Silloin näyttää kylvöruukun suurentaminen parantavan satoa huomattavasti enemmän kuin siinä tapauksessa, etteivät taimi- ja jatkokasvatusolosuhteet ole kovin suotuisat, kuten helmikuun alun kylvöksellä kokeissamme (taul. 5) valon suhteen (taul. 1) oli laita. Kylvöruukun tilavuuden vaikutus vähenee myös silloin, kun taimi- ja jatkokasvatusolosuhteet ovat suotuisat, kuten kevät ja kesäsalaatilla (taul. 5). Syyssalaatilla erot suurikokoisemman kylvöruukun hyväksi suurenevat taas jatkokasvatusolosuhteiden huonontuessa, kuten kokeissamme luonnonvalon vähetessä (taul. 1).

Taimikasvatusaikaa voidaan pidentää (kuva 1) silloin, kun taimikasvatusajan olosuhteet ovat edullisemmat kuin jatkokasvatusaikana. Tämä kuitenkin edellyttää, että kylvöruukun tilavuus on sitä suurempi mitä pitempi taimikasvatusaika on. Viimeaikaisten tutkimusten mukaan (BIERHUIZEN ym. 1973) salaatin kehityksessä on erotettavissa kolme vaihetta: itäminen, kasvu tämän jälkeen siihen asti, kun lehdet peittävät kasvualustan 100-prosenttisesti (lehdet 7—10 cm:n ruusukeasteella), sekä kasvu tästä sadonkorjuuvaiheeseen. Keskimmäinen, johon taimikasvatusvaihekin kuuluu, on ensisijaisesti riippuvainen lämpösummasta, ja kolmas vaihe valon määrästä. Näin ollen talvikauden eli kylmän vuodenajan taimikasvatusaikaa pidentämällä on mahdollista vähentää lämmityskustannuksia, koska kasvutila taimivaiheessa on pieni jatkokasvatuksen vaatimaan kasvutilaan verrattuna.

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THE CHEMICAL COMPOSITION OF FINNISH CUCUMBER MOSAIC VIRUS (CMV) AND CUCUMBER GREEN MOTTLE MOSAIC VIRUS (CGMMV)

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Two strain types can be distinguished in the present isolates of the cucumber mosaic virus (CMV), on the basis of their chemical composition and the symptoms induced by them in the host plants. Type CMV-CF causes slight systemic green mottling in cucumber; its average RNA-base composition is guanine 24.6, adenine 20.5, cytosine 22.5 and uracil 32.5 moles %. Its protein contains 16 amino acids and an average of 217 amino acid residues per subunit. Strain type CMV-LF causes systemic green mottling in cucumber and also pronounced stunting; its RNA-base composition is guanine 26.0, adenine 21.5, cytosine 22.0 and uracil 30.5 moles %. Its protein contains 17 amino acids, having methionine in addition to the 16 acids of the first strain type, and has 215 amino acid residues per subunit. — The isolates of the cucumber green mottle mosaic virus (CGMMV) are regarded as being of the English green mottle mosaic strain type CV3. Their average RNA-base composition is guanine 25.3, adenine 25.5, cytosine 19.2 and uracil 30.0 moles %. Their protein contains 15 amino acids and has an average of 160 amino acid residues per subunit.

INTRODUCTION

Even in more recent studies on cucumber mosaic virus the characterization of the isolates or strains has been done mainly with reference to their biological features in some host plants and to certain of their physical properties (BHARGAVA 1951, FRANCKI et al. 1966, HOLLINGS et al. 1968, LOVISOLO et al. 1968, LOVISOLO and CONTI 1969, TOMARU and UDAGAWA 1970, BOLTON and NUTTAL 1971, HÄNI 1971, MARCHAUX et al. 1971, HILL and SHEPHERD 1972, van REGENMORTEL et al. 1972, cf. references LINNASALMI 1966). Attention has also been paid to the serological properties of the strains (TOMLINSON et al. 1959, FRANCKI et al. 1966, LOVISOLO et al. 1968, SCOTT 1968, DEVERGNE and CARDIN 1970, TOMARU and UDAGAWA 1970, PELET and HÄNI 1971, DEVERGNE et al. 1972), but there are few studies dealing specifically with their chemical composition. Data have been published on the base composition of CMV-RNA by KAPER et al. (1965) and FRANCKI et al. (1966), and on the amino acid composition by LINNASALMI (1966) and van REGENMORTEL (1967 a).

The descriptions of the isolates/strains of cucumber green mottle mosaic virus have been based mainly on their symptomatology and pathogenicity in plants of the Cucurbitaceae (cf. LINNASALMI 1966), and also partly on their serological properties (BAWDEN and PIRIE 1937, KNIGHT and STANLEY 1941, KNIGHT 1955, van

Regenmortel 1967 b, Bawden and Kassanis 1968, Nozu et al. 1971). Chemical studies are scarce also in the case of this virus. Information on the base composition of CGMMV-RNA is given in the publications of Markham and Smith (1950) and Knight (1952). Results of the total amino acid analyses have been published by Knight (1947), Linnasalmi (1966), van Regenmortel (1967 b), and Funatsu and Funatsu (1968). Furthermore, studies have been made in Japan on the peptide composition and amino acid sequence of CGMMV occurring in that country (Nozu et al. 1971, Kurachi et al. 1972 a, b), and the protein of some CGMMV isolates was recently re-analysed by Tung and Knight (1972).

According to modern concepts of plant virology, the characterization of virus strains should be based not only on their biological and physical properties but also on knowledge of their chemical composition. For this reason, studies were continued on the chemical structure of isolates obtained from material of CMV and CGMMV collected in Finland in the years 1962—1965 (Linnasalmi 1966) by analysing the base composition of their RNA and the amino acid composition of their coat protein.

MATERIAL AND METHODS

The isolates of the CMV material were evidently of a strain type whose purification by present methods is very difficult and time-consuming. For this reason only five isolates were chosen from the material. These consisted of three isolates originally obtained from cucumber (*Cucumis sativus* L.) and two from tomato (*Lycopersicum esculentum* L.). Three isolates of CGMMV were studied.

The CMV material for the analyses was maintained chiefly in cucumber cv. Butcher's, and partly in *Nicotiana glutinosa* L.; the CGMMV isolates were maintained in Butcher's cucumber.

CMV was purified by the method of Scott (1963), as modified by Takanami and Tomaru (1969), in which gel filtration is used instead of dialysis. A Sephadex G-50 (Fine, 20—80 μ) gel, column K 25/45 was used. The filtrate was led through LKB Uvicord (type 4701 A) and the fraction containing the virus (absorbancy max. 260 nm) was purified by 2—3 runs of differential centrifugation (5 000 g/78 000 g). The yield was about 20 mg per 100 g of fresh leaf tissue, being approximately the same as that obtained earlier by the original method of Scott (Linnasalmi 1966). However, one advantage of the present method is that the purification procedure is more rapid and practical to perform, particularly since it reduces the amount of liquid at the centrifugation stage. CGMMV was purified by differential centrifugation as described earlier (Linnasalmi 1966).

RNA and protein were separated by the phenol method (Knight 1963).

The RNA-bases were separated after acid hydrolysis (1 N HCl 100°C 1 hr) by thin layer chromatography using the technique of Leech et al. (1968) with some modifications, and their concentrations were determined by UV spectrophotometry (for details, see Linnasalmi and Rashid 1969).

The amino acid analyses were made after acid hydrolysis (6 N HCl 110°C 24 hr) by the method of Spackman et al. (1958) using the Technicon Auto-Analyzer. However, the analyses for tryptophan were performed on unhydrolysed protein by the method of Graham et al. (1947) with some modifications, as follows: 2.5 mg protein, 3.5 ml 1 N NaOH containing 1 % gelatine, 0.5 ml 2.5 % p-dimethylaminobenzaldehyde in 10 % H_2SO_4, 0.2 ml 2 % $NaNO_3$ and 28 ml conc. HCl were shaken in a 100-ml volumetric flask, allowed to stand for 30 min and diluted with 50 % ethanol to 100 ml. After the colour development of 20 min, the reading was made at 600 nm in a Beckman DU spectrophotometer.

This method was compared with the method of Spies and Chambers (1949) used earlier by the senior author (LINNASALMI 1966). The results obtained by both methods showed rather good agreement. However, the method of GRAHAM et al. was more rapid and convenient, since, for example, the whole procedure can be performed in the light.

The estimates of the standard errors of RNA-base determinations in single measurements were calculated within isolates according to HALD 1952, p. 287, while the estimates of the standard error in single measurements of amino acid determinations were calculated according to HALD, p. 288.

RESULTS AND DISCUSSION

Cucumber mosaic virus (CMV)

RNA-base composition

The RNA-base composition of the CMV isolates analysed is presented in Table 1. The mean proportions of the purine and pyrimidine bases of four isolates (K 31/63, K 6/64, K 7/64, TK 144/63) expressed as moles % are guanine 24.6, adenine 20.5, cytosine 22.5, and uracil 32.5. The variation in the base composition between these isolates is so slight that they apparently cannot be considered to differ essentially from each other in this respect. TK 106/64 is distinguished from the former group of isolates by its somewhat smaller content of uracil (30.5) and its slightly larger content of guanine (26.0). According to analysis of variance, the difference for uracil was significant at the 95 % level ($F_{1,22} = 6.82$). For guanine, the difference was not significant at the 95 % level, but the F-value ($F_{1,22} = 4.27$) is very close to the figure required for significance at this level (4.30). There were no significant differences for adenine and cytosine ($F_{1,22} = 2.76$, $F_{1,22} = 0.58$).

The base composition of the Finnish isolates seems to be very similar to that of the QCMV strain analysed by FRANCKI et al. (1966); nor do the present results differ greatly from those obtained by KAPER et al. (1965) on strain CMV-Y. In those two studies the RNA-bases were separated by paper chromatography, while in this study thin layer chromatography was used. Both FRANCKI et al. (1966) and the present authors used 1 N HCl as hydrolysing agent, whereas KAPER et al. (1965) used 70 % $HClO_4$.

Amino acid composition

The amino acid compositions of the four CMV isolates (K 31/63, K 6/64, K 7/64, TK 144/63) are of the same order (Table 1). Amino acids which deviate from the mean value by more than one residue are aspartic acid, glutamic acid, glycine, tyrosine and arginine (2 residues), and serine and phenylalanine (4 residues). The total number of amino acid residues is almost the same in all the isolates, averaging 217 (range 216—218). The differences are so small that they do not give reason to speculate that the isolates represent different strains.

Likewise, the isolate TK 106/64 does not differ greatly from the isolates described above, apart from the fact that it contains the additional amino acid methionine, like the isolate CMV-S of van Regenmortel (van REGENMORTEL 1967 a, van REGENMORTEL et al. 1972). The total number of amino acid residues in both isolates is 215, but several amino acids show rather large residual differences (van REGENMORTEL et al. 1972). TK 106/64 contains more residues per subunit of glutamic acid, glycine, alanine and phenylalanine, and fewer residues of serine, methionine and arginine; in addition the amounts of the other amino acids differ by one residue, except for aspartic acid, valine, leucine and lysine.

The calculated molecular weights for the Finnish CMV coat protein subunits based on the amino acid analyses average about 23 800 (Table 1), which is near the values of 24 200 and

Table 1. RNA-base composition and amino acid composition of CMV.

Virus strain type	CMV-CF									CMV-LF	
Isolate	K 31/63		K 6/64		K 7/64		TK 144/63		Moles % average	TK 106/64	
Origin	*C. sativus* cv. Rheintraube		*C. sativus* cv. Arla		*C. sativus* cv. Arla		*L. esculentum* cv. Selandia			*L. esculentum* cv. Potentat	
RNA-bases [1]	Moles %									Moles %	
guanine	24.2		24.1		24.3		25.6		24.6	26.0	
adenine	20.7		21.3		19.7		20.3		20.5	21.5	
cytosine	22.6		22.5		22.8		22.0		22.5	22.0	
uracil	32.5		32.2		33.2		32.1		32.5	30.5	
standard error of base-means	0.51		0.62		0.55		0.55		0.28	0.62	
Amino acid residue[2]	Relative molar ratios [3]	Residues per subunit	Relative molar ratios [3]	Residues per subunit	Relative molar ratios [3]	Residues per subunit	Relative molar ratios [3]	Residues per subunit	Residues per subunit average	Relative molar ratios [3]	Residues per subunit
Asp	24.91	25	23.19	23	22.38	22	25.80	26	24	21.59	22
Thr	12.00	12	10.80	11	11.92	12	12.08	12	12	12.07	12
Ser	21.82	22	16.05	16	17.62	18	17.34	17	18	18.08	18
Glu	16.73	17	20.87	21	19.59	20	18.71	19	19	17.76	18
Pro	14.36	14	11.79	12	12.37	12	12.77	13	13	13.39	13
Gly	17.27	17	20.72	21	18.28	18	18.08	18	19	17.28	17
Ala	16.18	16	16.34	16	16.88	17	16.00	16	16	16.17	16
Val	16.36	16	15.18	15	16.09	16	15.63	16	16	15.63	16
Cys	0	0	0	0	0	0	0	0	0	0	0
Met	0	0	0	0	0	0	0	0	0	1.64	2
Ile	10.55	11	11.83	12	11.60	12	10.81	11	11	10.66	11
Leu	20.00	20	20.00	20	20.00	20	20.00	20	20	20.00	20
Tyr	5.09	5	4.38	4	6.70	7	6.58	7	6	7.49	7
Phe	6.00	6	12.85	13	8.77	9	8.05	8	9	8.03	8
Lys	15.27	15	13.72	14	14.37	14	14.12	14	14	14.32	14
His	2.91	3	4.23	4	3.35	3	2.71	3	3	3.55	4
Arg	16.91	17	13.14	13	15.17	15	13.42	13	15	15.39	15
Try	1.09	1	2.77	3	2.02	2	2.76	3	2	2.24	2
Total		217		218		217		216	217		215
Molecular weigth calculated	23 640		23 970		23 890		23 780		23 820	23 740	
TIP°C	72		72		76		64			76	

[1] Average of 4—6 determinations, standard error of a single measurement 1.239.

[2] Average of 2 analyses, except K 31/63 one analysis, K6/64 data from LINNASALMI 1966; standard error of a single measurement 0.966.

[3] Based on leucine as 20.

24 000 reported for the CMV coat protein subunit by HILL and SHEPHERD (1972) and by van REGENMORTEL et al. (1972).

Symptomatology

The symptoms induced in different host plants by the present Finnish CMV isolates from cucumber and tomato have been described in an earlier study (LINNASALMI 1966). Subsequent research, comprising many test series, has confirmed that these symptoms are as follows: in cucumber (cv. Butcher's), pale local primary lesions in the cotyledons, ± pronounced green mottling and mosaic in the true leaves; in *N. glutinosa*, ± severe mottling, curling and malformation of the leaves; in *Chenopodium quinoa* Willd., yellowish, later necrotic primary local lesions. Isolate TK 144/63 causes leaf narrowing symptoms in tomato. Only isolate TK 106/64 differs clearly from the others, causing more severe damage. Its stunting effect on cucumber is very strong; in one series of tests, for example, the plants after 2 months were 20—30 cm high as opposed to 70—90 cm for the cucumber plants infected by the other isolates. Isolate

TK 106/64 also induces very pronounced deformation and curling of the leaves in *N. glutinosa.* Its symptoms are fairly similar to those produced in the same plant species by Häni's (1971) CMV B type isolate. In the tomato, TK 106/64 causes symptoms of leaf narrowing.

Rather little information is available in the foreign literature on the symptoms caused in the host plants by the CMV strains/isolates whose chemical composition has been examined. CMV-Y, originally isolated from spinach in the USA, causes chlorosis and yellow and green mottle in cucumber (Sill and Walker 1952). We have not found any descriptions of the symptoms caused by the strain QCMV isolated from *Capsicum* sp. in Australia; for chemical analyses it was propagated in cucumber and *N. glutinosa* (Francki et al. 1966). CMV-S, isolated from the lupin in South Africa, causes mild mottle and chlorosis in tomato (cv. Pearson) and small local lesions in *Chenopodium amaranticolor*; there is no mention of the symptoms in cucumber or *N. glutinosa* (van Regenmortel 1961).

It seems possible to distinguish two strain types in the Finnish CMV isolate material on the grounds of their RNA-base composition, their amino acid composition and the symptoms they produce in the various host plants. CMV-CF is the more mildly pathogenic of the two types in cucumber and its coat protein is composed of 16 amino acids. CMV-LF is strongly pathogenic in both cucumber and tomato; it differs somewhat from the first type in the base composition of its RNA, and furthermore, it has a 17th amino acid, methionine, in addition to the 16 amino acids comprising the coat protein of the first type. It may be noted that the thermal inactivation point of the Finnish CMV isolates (Linnasalmi 1966) does not show a consistent correlation with their chemical composition or their biological properties (cf. Häni 1971).

Cucumber green mottle mosaic virus (CGMMV)

RNA-base composition

The RNA-base composition of the green mottle mosaic isolates is shown in table 2. The base compositions of the three Finnish isolates are very similar to each other and are likewise similar to the base compositions of cucumber virus 4 isolate analysed by Markham and Smith (1950) and CV3 and CV4 isolates analysed by Knight (1952). In the above investigations paper chromatography was used for separation of the RNA-bases, while the hydrolysing procedure was the same as in our analyses, 1 N HCl 100°C 1 hr.

Amino-acid composition

The amino acid analyses (Table 2) show that the compositions of the coat proteins of the Finnish CGMMV isolates are fairly similar to each other. The differences between their respective amino acids are of the order of one residue, except in the case of isolate K 5/67, which has three aspartic acid residues less than the average number per subunit. These differences might have become equalized if more analyses with different hydrolysing times had been performed on the isolates. The amino acid composition of these isolates is fairly similar to the composition of Berk CV3 protein (Tung and Knight 1972), both having 160 residues per subunit. It is also similar to the protein of van Regenmortel's strain CV4 (van Regenmortel 1967 b)[1]) and the protein of the Japan CGMMV-W strain analysed by Nozu et al. (1971), both of these strains having 158 residues. Owing to the small number of analyses published so far, it is difficult to decide with any certainty whether the comparatively small

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[1]) We agree with the opinion of Tung and Knight (1972) that van Regenmortel's CV4 may have been strain type CV3 (cf. Brčák et al. 1962, van Regenmortel 1967 b).

Table. 2. RNA-base composition and amino acid composition of CGMMV.

Isolate	K 5/67		K 14/62		K 16/62		
Origin	*C. sativus* cv. Butcher's		*C. sativus* cv. Butcher's		*S. sativus* cv. President		Moles % average
RNA-bases[1]	Moles %						
guanine	25.0		25.1		25.8		25.3
adenine	26.1		25.0		25.3		25.5
cytosine	19.0		19.1		19.4		19.2
uracil	29.9		30.8		29.4		30.0
standard error of base-means	0.23		0.23		0.23		0.13
Amino acid residue[2]	Relative molar ratios[3]	Residues per subunit	Relative molar ratios[3]	Residues per subunit	Relative molar ratios[3]	Residues per subunit	Residues per subunit average
Asp	16.44	16	20.06	20	19.84	20	19
Thr	10.05	10	10.85	11	10.53	11	11
Ser	20.93	21	22.27	22	21.28	21	22
Glu	10.00	10	10.00	10	10.00	10	10
Pro	9.95	10	9.32	9	9.26	9	10
Gly	5.82	6	6.36	6	6.22	6	6
Ala	20.05	20	20.85	21	20.43	20	20
Val	12.16	12	12.05	12	11.60	12	12
Cys	0	0	0	0	0	0	0
Met	0	0	0	0	0	0	0
Ile	7.73	8	8.58	9	7.82	8	8
Leu	12.47	12	11.99	12	12.18	12	12
Tyr	4.02	4	4.15	4	4.04	4	4
Phe	11.29	11	11.65	12	11.06	11	11
Lys	4.64	5	4.15	4	4.04	4	4
His	0	0	0	0	0	0	0
Arg	10.10	10	9.66	10	9.04	9	10
Try	1.19	1	1.14	1	1.28	1	1
Total		156		163		158	160
Molecular weight calculated	16 820		17 580		17 160		17 190
TIP°C	95		96		95		

[1] Average of 6 determinations, standard error of a single measurement 0.567.
[2] One analysis, K 14/62 and K 16/62 data from Linnasalmi 1966; standard error of a single measurement 0.966.
[3] Based on glutamic acid as 10.

differences of 1—2 amino acid residues are real or whether they are due to variations in analytical technique.

The amino acid composition of the Finnish isolates differs somewhat more from that of the yellow CV4 strains analysed by Tung and Knight (1972), and still more from the Japan CGMMV cucumber strain, which differs from all the above-mentioned strains in several of its properties. It contains one histidine residue per subunit and, for example markedly less proline and valine and more glycine, leucine and tryptophan (Funatsu and Funatsu 1968).

The calculated molecular weights for the Finnish CGMMV coat protein subunits based on the amino acid analyses average about 17 190 (Table 2), which is near the value of 17 100 reported for the Berk CV3 coat protein subunit by Tung and Knight (1972).

Symptomatology

The Finnish CGMMV isolates are symptomatologically very similar to Ainsworth's (1935) cucumber green mottle mosaic virus CV3. In the cucumber (*Cucumis sativus* L.) the isolates cause green mottle mosaic, crinkling and rugosity of the leaves (Linnasalmi 1966). Tung and

KNIGHT (1972) report that their green mottle mosaic virus Berk CV3 originates from England, and is thus obviously of the strain type CV3 described by AINSWORTH (1935). The CGMMV cucumber strain from Japan causes vein banding and dark green mosaic in cucumber (INOUYE et al. 1967). In the watermelon (*Citrullus vulgaris* Schrad.), the Finnish isolates, the English CV3 and the Japan CGMMV-W cause weak systemic mottling (AINSWORTH 1935, LINNASALMI 1966, KOMURO et al. 1971). A feature shared by the Finnish isolates and the English CV3 is their inability to infect plants other than the *Cucurbitaceae* (AINSWORTH 1935, BAWDEN and PIRIE 1937, LINNASALMI 1966); in contrast, local lesion symptoms are caused by the Japan CGMMV isolate from cucumber in *Datura stramonium* and *Petunia hybrida* and by CGMMV-W in *Chenopodium amaranticolor* (INOUYE et al. 1967, NOZU et al. 1971).

On the basis of the symptoms induced in plants of the *Cucurbitaceae*, as well as the RNA-base composition and the amino acid composition of their coat proteins, the Finnish CGMMV isolates can be regarded as being of the English CV3 green mottle mosaic strain type.

SUMMARY

Two strain types can be distinguished in the present CMV material on the basis of their RNA-base composition and their amino acid composition, and the symptoms induced in various host plants. CMV-CF causes systemic green mottling symptoms and slight stunting in cucumber (isolates K 31/63, K 6/64, K 7/64, TK 144/63). Only the isolate TK 144/63 causes leaf narrowing in tomato, having been originally obtained from that plant. The average base composition of the RNA of this strain type, expressed as moles %, is guanine 24.6, adenine 20.5, cytosine 22.5 and uracil 32.5. Its protein contains 16 amino acids and an average of 217 residues per subunit. Strain type CMV-LF (isolate TK 106/64), which in addition to green mottle causes marked stunting in cucumber and leaf narrowing symptoms in tomato, contains guanine 26.0, adenine 21.5, cytosine 22.0 and uracil 30.5 moles %. It contains 17 amino acids, having methionine in addition to the 16 found in the CMV-CF strain type, and has 215 amino acid residues per subunit (Table 1).

The CGMMV isolates (K 5/67, K 14/62, K 16/62) are regarded as being of the English green mottle mosaic strain type CV3; in cucumber they cause strong green mottling, crinkling and some stunting of the leaves. The average proportions of their RNA-bases, expressed as moles % are guanine 25.3, adenine 25.5, cytosine 19.2, and uracil 30.0. Their protein contains 15 amino acids and has an average of 160 residues per subunit (Table 2).

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REFERENCES

AINSWORTH, G. C. 1935. Mosaic diseases of the cucumber. Ann. Appl. Biol. 22: 55—67.

BAWDEN, F. C. & KASSANIS, B. 1968. The serological relationship between tobacco mosaic virus and cucumber viruses 3 and 4. Virology 34: 174—175.

— & PIRIE, N. W. 1937. Liquid crystalline preparations of cucumber viruses 3 and 4. Nature 139: 546—547.

BHARGAVA, K. S. 1951. Some properties of four strains of cucumber mosaic virus. Ann. Appl. Biol. 38: 377—388.

BOLTON, A. T. and NUTTALL, V. W. 1971. A highly virulent strain of cucumber mosaic virus occurring in cucumber in eastern Ontario. Can. Plant Dis. Survey 51: 138—141.

BRČÁK, J., ULRYCHOVÁ, M. & ČECH, M. 1962. Infection of tobacco and some Chenopodium species by the cucumber virus 4 (and 3) and by its nucleic acid. Virology 16: 105—114.

Devergne, J.-C. & Cardin, L. 1970. Étude sérologique comparative de plusieurs isolats du virus de la mosaïque du concombre (CMV). Ann. Phytopathol. 2: 639—661.

— Marrou, J., Lot, H. & Cardin, L. 1972. Contribution a l'étude du virus de la mosaïque du concombre (CMV). I. — Influence de différentes solutions salines sur le pouvoir infectieux, la stabilité et les propriétés antigéniques de deux isolats. Ann. Phytopathol. 4: 5—23.

Francki, R. I. B., Randles, J. W., Chambers, T. C. & Wilson, S. B. 1966. Some properties of purified cucumber mosaic virus (Q strain). Virology 28: 729—741.

Funatsu, G. & Funatsu, M. 1968. Chemical studies on proteins from two tobacco mosaic virus strains. Phytopathol. Soc. Japan, 9 p. Tokyo 1968.

Graham, C. E., Smith, E. P., Hier, S. W. & Klein, D. 1947. An improved method for the determination of tryptophane with p-dimethylaminobenzaldehyde. J. Biol. Chem. 168: 711—716.

Hald, A. 1952. Statistical Theory with Engineering Applications. 783 p. New York.

Hill, J. H. & Shepherd, R. J. 1972. Molecular weights of plant virus coat proteins by polyacrylamide gel electrophoresis. Virology 47: 817—822.

Hollings, M., Stone, O. M. & Brunt, A. A. 1968. Cucumber mosaic virus. Ann. Rep. Glasshouse Crops Res. Inst. 1967: 95—98.

Häni, A. 1971. Zur Epidemiologie des Gurkenmosaikvirus im Tessin. Phytopath. Z. 72: 115—144.

Inouye, T., Inouye, N., Asatani, M. & Mitsuhata, K. 1967. Studies on cucumber green mottle mosaic virus in Japan. — Ber. Ohara Inst. landw. Biol. 14: 49—69. (Ref. Rev. Appl. Mycology 47: 315.)

Kaper, J. M., Diener, T. O. & Scott, H. A. 1965. Some physical and chemical properties of cucumber mosaic virus (strain Y) and of its isolated ribonucleic acid. Virology 27: 54—72.

Knight, C. A. 1947. The nature of some of the chemical differences among strains of tobacco mosaic virus. J. Biol. Chem. 171: 297—308.

— 1952. The nucleic acids of some strains of tobacco mosaic virus. J. Biol. Chem. 197: 241—249.

— 1955. Are cucumber viruses 3 and 4 strains of tobacco mosaic virus? A review of the problem. Virology 1: 261—267.

— 1963. Chemistry of viruses. Protoplasmatologia IV, 2, 177 p. Wien 1963.

— & Stanley, W. M. 1941. Preparation and properties of cucumber virus 4. J. Biol. Chem. 141: 29—38.

Komuro, Y., Tochihara, H., Fukatsu, R., Nagai, Y. & Yoneyama, S. 1971. Cucumber green mottle mosaic virus (Watermelon strain) in watermelon and its bearing on deterioration of watermelon fruit known as "Konnyaku disease". Ann. Phytopathol. Soc. Japan 37: 34—42. (Ref. Rev. Plant Pathology 51: 176.)

Kurachi, K., Funatsu, G. & Funatsu, M. 1972 a. Amino acid composition of cucumber green mottle mosaic virus coat protein and sequence determination of its tryptic peptides. Agr. Biol. Chem. 36: 937—946.

— Funatsu, G., Funatsu, M. & Hidaka, S. 1972 b. Partial amino acid sequence of cucumber green mottle mosaic virus coat protein. Agr. Biol. Chem. 36: 1109—1116.

Leech, R. M., Dyer, T. A., Poole, C. E. & Smith, W. 1968. The determination of base ratios of very small samples of ribonucleic acid using thin layer chromatography. J. Chromatography 34: 364—369.

Linnasalmi, A. 1966. Virus diseases of cucumber in Finland and characteristics of their causal agents cucumber mosaic and cucumber green mottle mosaic viruses. Ann. Agr. Fenn. 5: 305—323.

— & Rashid, R. 1969. Base composition of ribonucleic acid in tobacco mosaic virus and potato virus X isolates from tomato. Finn. Chem. J. 42: 455—459.

Lovisolo, O., Conti, M. & Luisoni, E. 1968. Su di un ceppo del virus del mosaico del Cetriolo (CMV) isolato da Garofano. Phytopath. Mediterranea 7: 71—76.

— & Conti, M. 1969. Biological characterization of some isolates of cucumber mosaic virus. Ann. Phytopath. Hors série 1: 367—373.

Marchoux, G., Quiot, J.-B., Marrou, J. & Lot, H. 1971. Modification par l'hôte d'une caractéristique biologique de différentes "souches" du virus de la mosaïque du concombre. Ann. Phytopathol. 3: 423—429.

Markham, R. & Smith, J. D. 1950. Chromatographic studies on nucleic acids. 3. The nucleic acids of five strains of tobacco mosaic virus. Biochem. J. 46: 513—517.

Nozu, Y., Tochihara, H., Komuro, Y. & Okada, Y. 1971. Chemical and immunological characterization of cucumber green mottle mosaic virus (watermelon strain) protein. Virology 45: 577—585.

Pelet, F. & Häni, A. 1971. Dosage du virus de la mosaïque du concombre par la spectrophotométrie, la sérologie et l'infectivité. Recherche agronomique en Suisse 10: 94—110.

Regenmortel, M. H. V. van 1961. Zone electrophoresis and particle size of cucumber mosaic virus. Virology 15: 221—223.

— 1967 a. Biochemical and biophysical properties of cucumber mosaic virus. Virology 31: 391—396.

— 1967 b. Serological studies on naturally occurring strains and chemically induced mutants of tobacco mosaic virus. Virology 31: 467—480.

— Hendry, D. A. & Baltz, T. 1972. A reexamination of the molecular size of cucumber mosaic virus and its coat protein. Virology 49: 647—653.

Scott, H. 1963. Purification of cucumber mosaic virus. Virology 20: 103—106.

Soctt, H. A. 1968. Serological behavior of cucumber mosaic virus (strain Y) and the virus protein. Virology 34: 79—90.

Sill, W. H. Jr. & Walker, J. C. 1952. A virus inhibitor in cucumber in relation to mosaic resistance. Phytopath. 42: 349—352.

Spackman, D. H., Stein, W. H. & Moore, S. 1958. Automatic recording apparatus for use in the chromatography of amino acids. Anal. Chem. 30: 1190—1206.

Spies, J. R. & Chambers, D. C. 1949. Chemical determination of tryptophan in proteins. Anal. Chem. 21: 1249—1266.

Takanami, Y. & Tomaru, K. 1969. Effect of EDTA on cucumber mosaic virus and its application in purification. Virology 37: 293—295.

Tomaru, K. & Udagawa, A. 1970. Strains of cucumber mosaic virus isolated from tobacco plants VI. A yellow mild mottle strain. Ann. Phytopath. Soc. Japan 36: 87—93.

Tomlinson, J. A., Shepherd, R. J. & Walker, J. C. 1959. Purification, properties, and serology of cucumber mosaic virus. Phytopath. 49: 293—299.

Tung, J-S. & Knight, C. A. 1972. The coat protein subunits of cucumber viruses 3 and 4 and a comparison of methods for determining their molecular weights. Virology 48: 574—581.

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SELOSTUS

Kurkun mosaiikkiviruksen (CMV) ja kurkun vihermosaiikkiviruksen (CGMMV) kemiallinen koostumus

Annikki Linnasalmi ja Anneli Toiviainen

Maatalouden tutkimuskeskus

Koska virusrotujen karakterisointi edellyttää, paitsi niiden biologisten ja fysikaalisten ominaisuuksien tuntemusta, tietoja myös niiden kemiallisesta koostumuksesta, jatkettiin Suomessa v. 1962—65 kootun kurkun mosaiikkivirus (CMV)- ja kurkun vihermosaiikkivirus (CGMMV)-aineiston (Linnasalmi 1966) kemiallisen rakenteen selvittämistä. Määritettiin isolaattien ribonukleiinihapon (RNA) emäskoostumus sekä niiden kuoriproteiinin aminohappokoostumus.

CMV-aineistossa voidaan isolaattien RNA-emäskoostumuksen ja aminohappokoostumuksen sekä niiden eri isäntäkasveissa aiheuttamien symptomien nojalla erottaa kaksi rotutyyppiä. CMV-CF aiheuttaa kurkussa systeemiset viherkirjosymptomit ja lievää kitukasvuisuutta (isolaatit K 31/63, K 6/64, K 7/64, TK 144/63). Isolaateista vain alunperin tomaatista eristetty TK 144/63 aiheuttaa tässä kasvilajissa suikalelehtisyyttä. Rotutyypin keskimääräinen RNA -emäskoostumus on mooli-%:na: guaniini 24.6, adeniini 20.5, sytosiini 22.5 ja urasiili 32.5. Sen proteiini sisältää 16 aminohappoa ja keskimäärin 217 happotähdettä/alayksikkö. Rotutyypin CMV-LF (isolaatti TK 106/64), joka viherkirjon lisäksi aiheuttaa kurkussa voimakasta kitukasvuisuutta sekä tomaatissa suikalelehtisyyttä, sisältää guaniinia 26.0, adeniinia 21.5, sytosiinia 22.0 ja urasiilia 30.5 mooli-% sekä CMV-CF rotutyypin kanssa samojen 16 aminohapon lisäksi metionin eli yhteensä 17 aminohappoa, 215 happotähdettä/alayksikkö (taul. 1).

CGMMV-isolaatit (K 5/67, K 14/62, K 16/62) ovat kaikki lähinnä englantilaista CV3 -viherkirjorotutyyppiä, aiheuttaen kurkun lehdissä voimakkaan viherkirjon ja ryppyisyyden sekä jonkin verran kitukasvuisuutta. Isolaattien keskimääräinen RNA -emäskoostumus on: guaniini 25.3, adeniini 25.5, sytosiini 19.2 ja urasiili 30.0 mooli-%. Niiden proteiini sisältää 15 aminohappoa, keskimäärin 160 happotähdettä/alayksikkö (taul. 2).

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THE EFFECT OF HEAVY NITROGEN FERTILIZATION ON SWARD DENSITY AND WINTER SURVIVAL OF GRASSES

Erkki Huokuna and Sirkka-Liisa Hiivola

Huokuna, E. & Hiivola, S.-L. 1974. **The effect of heavy nitrogen fertilization on sward density and winter survival of grasses.** Ann. Agric. Fenn. 13: 88—95.

In experiments with meadow fescue (*Festuca pratensis*) and cocksfoot (*Dactylis glomerata*) under Finnish conditions (lat. 60—64°) the application of nitrogen fertilization in quantities of 300 kg/ha upwards per year weakened the plants so that rather extensive damage occurred following difficult winter conditions. The greatest damage occurred when both the duration and depth of the snow covering were great and the previous autumn's crop had been cut in mid September.

Even when severe winter damage did not occur, swards which had received a heavy dose of nitrogen fertilizer were less dense, although the crops were large in spite of this. In some cases, even with 300 kg/ha of nitrogen fertilizer the swards maintained a satisfactory density for five years.

INTRODUCTION

Experiments to study the effect of nitrogen fertilization on grasses have been carried out extensively in various parts of the world, but up to now the quantities applied have been relatively small. Nitrogen has been demonstrated to have a particularly strong effect in both increasing the crop and as a factor altering quality (Jäntti and Köylijärvi 1964). The reduction in the cost of nitrogen fertilizers has, however, already led to greater quantities being used in agricultural practice, the Netherlands being a good example ('t Hart 1964). Several researchers have investigated the effect of large quantities of nitrogen and have demonstrated it to be on the whole favourable (de Boer 1966, Steen 1972).

Nevertheless, the results of research carried out in Central Europe may not be relied upon as applicable to Finnish conditions without modification, since among other things soil, duration of daylight and winter conditions are essentially different from those in, for example, the Netherlands. As the use of heavy nitrogen fertilizers appeared to be rather advantageous economically and a means of augmenting self-supporting protein production, the Agricultural Research Centre, in association with the Peat Society's experimental stations and the Åland experiment station, organised an extensive series of field experiments in various parts of the country, spanning the years 1966—70.

The aim of this research was to determine

This study was initiated by Professor August Jäntti († 1968). Besides the team of authors, several of the directors of the experiment stations were responsible for carrying out the field experiments.

the extent to which large quantities of nitrogen could be used continuously under Finnish conditions on meadow fescue and cocksfoot swards harvested at silage stage and, above all, to determine the effects that a large amount of nitrogen has on the plants' endurance, crop yield and quality, and the soil's nutrient condition.

MATERIAL AND METHODS

This study was begun in 1966, when the swards were sown at 11 experimental sites in various parts of the country (Fig. 1). The following year, according to the same plan, seven new trials swards were sown, some of them at new experimental sites. The soil types in these trial fields varied from clay to peat and the soil's nutrient status was satisfactory (Table 1).

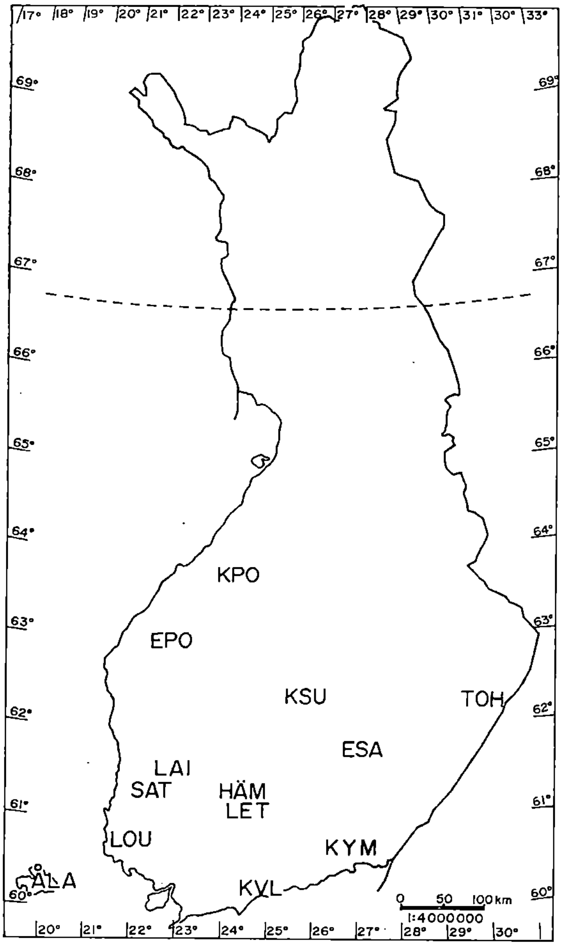

Fig. 1. Experimental sites. For symbols see Table 1.

The experiments were set up using 4 replicates of split-plot, randomized blocks, so that plant species (2 at each experimental site) formed the main plots and nitrogen fertilization the subplots. The size of the subplots was approximately 10 m^2.

Grass species, varieties and seed rates used were as follows:

meadow fescue	Tammisto	30 kg/ha
cocksfoot	Tammisto	30 kg/ha

The quantities of nitrogen used for the experiments were: 0, 150, 300, 450 and 600 kg of nitrogen per hectare. The nitrogen fertilizer employed was calcium-ammoniumsaltpetre (Oulunsalpietari), where the nitrogen (26 %) is half ammonium- and half nitrate-nitrogen. In addition, it contains 3 % Mg and 6 % Ca. The nitrogen was spread in three equal dressings, the first at the beginning of the growing season, in May, and the following two directly after the first and second cuttings. The yearly PK fertilization varied slightly between the different experimental sites, being usually 500 kg/ha of superphosphate and 200 kg/ha of muriate of potash (60 % K_2O) (Table 2). In fact the amount of potassium used on coarse mineral soils averaged 100 kg of potassium per hectare, for fine mineral soils 90 kg K/ha and for organogenic soils 120 kg K/ha. PK fertilization was spread in one dressing at the beginning of the growing season.

The crop was harvested at the beginning of the heading stage, at most 3 times during the summer. The first cut took place between the 5th and 15th of June, the second at the end of July/beginning of August and the third during the last days of August or in September. Analyses were made from grass samples to determine the content of dry matter, total nitrogen, crude

Table 1. Experimental sites, soil types and state of plant nutrition in the fields at the beginning of the experiment.

Site		Year established	Soil type	pH_{H_2O}	Ca	K	P
					mg/l 1)		
			Coarse mineral soil:				
LAI	Pasture Exp.Sta.	1966	Coarse fine sand	6.4	1 680	235	36.3
ESA	South Savo Exp.Sta.	1966	—„—	6.1	1 550	95	11.5
	—„—	1967	—„—	5.7	800	120	8.3
KPO	Central Ostrobothnia Exp.Sta.	1966	Fine sand	5.1	360	120	7.1
TOH	Peat Soc. Exp.Sta.	1966	—„—	5.9	1 150	135	3.5
HÄM	Häme Exp.Sta.	1966	Sandy moraine	5.6	1 360	170	15.3
SAT	Satakunta Exp.Sta.	1967	Coarse fine sand	6.2	1 160	50	18.9
			Fine mineral soils:				
KVL	Inst. of Plant Husb.	1966	Sandy clay	6.0	2 160	260	5.1
„	—„—	1967	Silty clay	5.7	2 450	240	5.7
SAT	Satakunta Exp.Sta.	1966	Sandy clay	5.6	1 440	205	9.9
KYM	Kymenlaakso „	1966	Silty clay	6.6	2 870	200	13.8
EPO	South Ostrobotnia Exp.Sta.	1966	Clayey silt	5.6	1 310	260	10.3
LOU	Southwest Finland Exp.Sta.	1966	Heavy clay	6.1	2 490	350	19.9
	—„—	1967	Sandy clay	6.0	1 620	190	15.8
ÅLA	Åland Exp.Sta.	1967	Sandy clay	5.9	2 040	125	7.3
KSU	Central Finland Exp.Sta.	1967	Loamy silt	5.6	980	70	4.3
			Organogenic soils:				
LET	Peat Soc.Exp.Sta.	1966	Spaghnum peat	5.1	1 770	110	21.4
KPO	Central Ostrobothnia Exp.Sta.	1967	Mould	5.0	610	120	7.6

1) Acid ammonium acetate (pH 4.65) extractable.

fibre, crude fat, ash and nitrogen-free extracts as well as the mineral content from ash.

Statistical analyses of the results were carried out by the Computing Service of the Agricultural Research Centre.

Weather conditions

Weather conditions at the different experimental sites varied quite substantially from one to another and from year to year. To give a general idea of the weather throughout the experimental period, it may be mentioned that the summer of 1967 was favourable throughout the greater part of the country, only the west coast suffered a dry July. During the following years, 1968—70, most of the country had a season significantly drier than average (Table 3) and the midsummer rainfall especially was below normal. The average temperatures varied relatively little between the different experiment sites over the years. In May the average temperature was around 8—10°C, in June 13—

Table 2. Nutrients given in fertilizers for different levels of nitrogen fertilization.

N	K	Ca	P	Mg	Na	Fe
			kg/ha/yr			
0	97	100	44	1	2.0	1.5
150	97	135	44	19	2.0	1.5
300	97	170	44	37	2.0	1.5
450	97	205	44	55	2.0	1.5
600	97	240	44	73	2.0	1.5

Table 3. Precipitation 15/5—1/9 at the different experimental sites for years 1967, 1968, 1969 and 1970.

	Precipitation mm			
	1967	1968	1969	1970
LAI	247	113	90	210
ESA	182	202	192	185
KPO	262	76	48	136
TOH	166	136	148	172
HÄM	216	163	148	150
KVL	184	159	109	174
SAT	246	121	87	163
KYM	151	166	118	170
EPO	332	100	60	182
LOU	286	124	126	191
ÅLA	176	98	157	76
KSU	247	152	148	213
LET	199	226	141	124

15 °C, in July 14—17 °C, in August 14—16 °C and in September 8—12 °C.

The depth and duration of the snow covering and the depth of ground frost varied greatly between the areas and between different years (Table 4). In the coastal areas of South and West Finland, the snow cover was normally less than in inland regions. The depth of ground frost in periods of abundant snow remained rather slight. An exceptionally long period of snow occurred in Central and North Finland during the year 1967—68. There was a great deal of snow throughout the whole winter and in many places the ground did not freeze at all.

Table 4. Periods of continuous snow covering, depth of snow and of ground frost for years 1966—1970, in South, East and West Finland (KVL, TOH, ESA, EPO).

	Days of snow cover	Snow depth	Depth of ground frost	Date of the frost melting
		cm 15.3.	cm	
KVL				
1966/67	130	50	15	13.4.
1967/68	127	32	61	30.4.
1968/69	129	57	45	28.4.
1969/70	154	60	44	4.5.
TOH				
1966/67	146	36	2	17.4.
1967/68	166	68	13	2.5.
1968/69	156	62	17	8.5.
1969/70	172	51	11	30.4.
ESA				
1966/67	144	41	11	28.4.
1967/68	137	62	31	8.5.
1968/69	135	50	28	6.5.
1969/70	162	53	12	8.5.
EPO				
1966/67	114	16	28	11.4.
1967/68	130	31	26	12.4.
1968/69	139	24	42	24.4.
1969/70	169	41	43	1.5.

RESULTS

The establishment of the experimental swards was fairly successful in all cases. The stands were dense and even at the beginning of the first growing season. The largest dressings of N did not result in any damage to start with. The plants were more luxuriant and a darker green in colour when more nitrogen was applied. Only in the third year, at three sites (KVL, ESA, LOU), was it observed that the larger quantities of N-fertilizer (300—600 kg/ha) applied at the summer's third spreading, produced withered leaves and killed whole tillers when a period of drought occurred.

Winter damage

In all experiments where 150 kg of N-fertilization were used the swards were of full density. On the other hand, with 300—600 kg/ha of nitrogen the tillers were thinned out although no winter damage or sudden withering of shoots similar to that mentioned above was observed (Fig. 2).

The larger the quantities of nitrogen fertilization applied, the greater the winter damage (Table 5). In the plots which had received a large amount of nitrogen (450 and 600), winter damage occurred to a much greater degree ($P < 0.001$) than in plots which received little (150) nitrogen. The regression of the percentage of winter damage on the amount of nitrogen given was highly significant:

$$\text{winter damage-}\% = 6.58 + 0.032\,N \ (R = 0.29^{***},\ \text{df; } 1,\ 358),$$

according to which, in this study, a 100 kg increase in nitrogen quantity augmented winter damage by an average of a 3 % unit.

The difference occurring between species was also significant ($P < 0.05$). Cocksfoot was a little weaker than meadow fescue. There were also very clear differences between soil types. In fine mineral soils there were significantly less winter damages than in coarse mineral soils ($P < 0.001$). However, the statistics do not give an entirely

Fig. 2. The density of meadow fescue sward after two years experiment period. Treatments from the left 600, 300, 150, and 450 kg/ha N.

correct picture here as the fine mineral soils in Finland are principally sited in the southern and western parts of the country, whereas coarse mineral soils are usually found in the eastern and northern areas, where the snow covering, which has a decided effect on how the plants winter, is usually thick. In this investigation the peat soils also happened to be rather better situated than usual, as they were sited, on average, in slightly more favourable areas.

The age of the swards was decisive with regard to the plants' winter survival (Table 5). The difference between the second and third years was highly significant ($P < 0.001$). The older the swards, the greater the winter damage.

Weather conditions during the winter also had a marked effect on survival. The damages in the spring of 1969 were very significantly greater than those occurring in the years 1968 and 1970. Swards which had received 300—600 kg/ha of nitrogen the previous year were almost entirely destroyed. The greatest damage was observed in areas with abundant snow, even though the thickness and duration of the snow covering did not entirely explain the differences occurring between experimental sites. Winter damage was also observed in the spring of 1968 although the thickness and duration of the snow covering had been fairly normal and the land had been frozen over at every site.

Of particular importance to winter damage was the date of the last cutting. The later the cutting, that is the smaller the sum of the effective daily average temperature exceeding 5 °C after the final cut, the greater the damage (Table 5).

Botanical composition of the crop

From the crops cut, an analysis was made of the botanical composition of each harvest. In cases where no heavy winter damage had occurred, the swards which received nitrogen fertilization were nearly all pure (Table 6). Differences between the amounts of nitrogen fertilizer given were very small. The other species present were principally *Poa pratensis*, *Agropyron repens* and *Taraxum officinale*. In the plots which had not been fertilized there was abundant white clover, *Trifolium repens*. The larger the quantity of nitrogen fertilizer, the smaller the proportion of white clover.

Table 5. Damage caused during winters 1967/68, 1968/69 and 1969/70, as % of the stand.

F-values of variance analysis. The figures for degrees of freedom are indicated in parentheses

NITROGEN FERTILIZATION

N kg/ha/yr	0	150	300	450	600		
%	9.4^{a}	8.3^{a}	14.8^{ab}	22.1^{bc}	26.6^{c}	8.9^{***}	(4, 355)

SPECIES

	Meadow fescue	Cocksfoot		
%	13.1^{a}	19.4^{b}	6.5^{*}	(1, 358)

SOILS

	Coarse mineral	Fine mineral	Organogenic		
%	22.5^{b}	11.3^{a}	16.7^{ab}	9.2^{***}	(2, 357)

LEY YEAR

	2	3		
%	11.2^{a}	21.2^{b}	16.7^{***}	(1, 338)

YEAR

	1968	1969	1970		
%	13.3^{a}	21.9^{b}	6.3^{a}	13.1^{***}	(2, 357)

DAY DEGREE SUMMATION after last cut (above 5°C)

	< 100°	101°—200°	> 200°		
%	23.7^{b}	12.7^{a}	9.2^{a}	14.4^{***}	(2, 357)

The TUKEY test (Steele and Torrie 1960) was applied to test the differences between the averages : a, b, c, $P < 0.05$. Values followed by the same letter do not differ significantly from each other.

Levels of significance:

$*$ $P \leqq 0.05$
$**$ $P \leqq 0.01$
$***$ $P \leqq 0.001$

There were no differences between the spring and autumn cuts, but in the midsummer cut (cut 2), the proportion of unsown species in the herbage crop was significantly higher than in the others.

The proportion of other plant species increased with the age of the swards, but differences were not significant until comparisons were made between the second and third years. Differences were very slight between soil types, nor were there any significant differences between the species of grass.

DISCUSSION

The weakening effect of heavy nitrogen fertilization on the winter resistance of the grasses was decisive for second year and older swards. The largest quantities of nitrogen, 450 and 600 kg/ha, were seen to be too large to maintain to the plants' winter hardiness. Prevailing unfavourable factors all caused extensive damage in these plots. On the other hand, 300 kg/ha appeared to lie within the bounds of tolerance. In many cases this too brought about a thinning out of the swards and in some cases almost complete destruction. But usually, these swards survived distinctly better than those which had received more nitrogen. The swards which had received 150 kg/ha of nitrogen were the hardiest. These survived better than those which had received only PK fertilization.

In seeking an explanation for the differ-

Table 6. Percentage sown grasses in stand.

						F-values of variance analysis. The figures for degrees of freedom are indicated in parentheses	
NITROGEN FERTILIZATION N kg/ha/yr	0	150	300	450	600		
%	80.5^{a}	93.9^{b}	94.2^{b}	93.8^{b}	93.0^{b}	65.6***	(4, 1594)
CUT no.	1	2	3				
%	92.1^{b}	88.9^{a}	92.0^{b}			9.5***	(2, 1596)
LEY YEAR	1	2	3				
%	94.7^{b}	93.7^{b}	84.4^{a}			94.4***	(2, 1596)
SOILS	Coarse mineral	Fine mineral	Organogenic				
%	90.7^{ab}	91.9^{b}	88.7^{a}			4.2*	(2, 1596)
SPECIES	Meadow fescue	Cocksfoot					
%	91.4^{a}	90.8^{a}				0.6	(1, 1597)

For meaning of index letters, see Table 5.

Levels of significance:
* $P \leqq 0.05$
** $P \leqq 0.01$
*** $P \leqq 0.001$

ences in winter hardiness during the different years and in the various growing areas, it was verified that, on average, plants in fine mineral soils survived the winter better than those on coarse mineral and organogenic soils (Table 5). However, total destruction did also occurr on fine mineral soils. Nevertheless, the differences between soil types in Table 5 are not attributable only to the type of soil, although this does play some part (c.f. Baadshaug 1973), in that fine mineral soils prevail in South and Southwest Finland where winter conditions are in any case more favourable (short winter season, thin snow layer and normally frozen-over ground).

Potassium fertilization has been proved to promote the resistance of plants to disease (Nissinen 1970). In this study, very great differences in the soil's potassium content existed between the various experimental sites, but this did not constitute a decisive divider between cases of good and bad wintering. Nevertheless, winter survival was generally better on fine mineral soils with abundant potassium than on coarse mineral and organogenic soils where the potassium content was lower.

The date of the last cut in autumn varied between the different sites. It appeared that the greatest winter damage occurred when the third cutting of the previous year had taken place in September. The earlier the cutting was performed, the better the plants wintered. The reason for this is that under the conditions in question, the growing season normally ends in October, when plants which have been cut 3—4 weeks earlier have exhausted their store of carbohydrates to the minimum in producing new leaves. This explanation has been supported by other research (Huokuna 1971). If, after the final cut, there occurred a sufficiently long warm spell for the accumulation of a new energy store, winter damage was reduced.

A long period (6—7 months) of snow covering combined with ground that has remained unfrozen, constitute the most difficult circumstances for plants weakened by heavy nitrogen fertilization. Winter diseases were seldom found among the dead plants; it appeared rather that the plants died as a result of having exhausted their store of energy, since, in unfrozen soil, the consumption needed for respiration purposes was too great. All swards wintered satisfactorily in ground that was frozen to a depth of at least 10 cms (HUOKUNA 1971 a).

The significance to winter survival of the ground being frozen over is demonstrated in other investigations where swards weakened by fertilization have wintered succesfully if, on arrival of the first frost, the snow is packed, for example by driving a tractor over it. Even light packing of the snow surface weakens the snow's insulating power and the land freezes (HUOKUNA 1971 a).

Winter damage has a decisive effect on crop quantities. In fact it appears that a slight thinning (10—15 %) of a dense stand (3 600 shoots/m^2) does not affect the yield as tiller formation is fairly abundant in swards receiving nitrogen fertilization (HUOKUNA 1966) and stands cut at the heading stage form a full canopy in good time to produce the maximum output.

REFERENCES

BAADSHAUG, O. H. 1973. Effects of soil type and soil compaction on the wintering of three grass species under different wintering condition. Acta Agr. Scand. 23: 77—86.

BOER, TH. A. DE. 1966. Nitrogen effect on the herbage production of grasslands on different sites. Proc. 10. Int. Grassl. Congr. 199—204.

HART, M. L.'t. 1964. Innehållet av olika kemiska komponenter i gräs vid intensiv betesskötsel. Nord. Jordbr.forskn. Suppl. 9: 665—675.

HUOKUNA, E. 1966. Tillering in meadow-fescue swards. Proc. 10. Int. Grassl. Congr. 129—134.

— 1971. Gödslingens inverkan på gräsens övervintringsförmöga. Nord. Jordbr.forskn. 53: 315—316.

— 1971 a. Runsaan typpilannoituksen saaneiden nurmien talvehtiminen. Karjatalous 47: 92—93.

JÄNTTI, A. & KÖYLIJÄRVI, J. 1964. Laidunnurmien typpiväkilannoituskokeiden tuloksia. Summary: Results of nitrogen fertilization on pasture. Ann. Agric. Fenn. 3: 165—214.

NISSINEN, O. 1970. Effects of minerals on the resistance of English ryegrass to Fusarium nivale (Fr.) Ces. Peat & Plant News 2: 3—11.

STEELE, R. G. & TORRIE, J. H. 1960. Principles and procedures of statistics. 481 p. New York.

STEEN, E. 1972. Stigande mängder kväve till fem vallgräsarter skördade tre gånger per säsong. Lantbr.-högsk. Medd. A. 176.

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SELOSTUS

Runsaan typpilannoituksen vaikutus nurmen tiheyteen ja kasvien talvehtimiseen

ERKKI HUOKUNA ja SIRKKA-LIISA HIIVOLA

Maatalouden tutkimuskeskus

Suomen oloissa (60—64° pl.) suoritetuissa nurminadan (*Festuca pratensis*) ja koiranheinän (*Dactylis glomerata*) typpilannoituskokeissa heikensivät 300 kg/ha N vuodessa ja sitä suuremmat määrät kasveja niin, että vaikeissa talvehtimisoloissa vauriot muodostuivat hyvin suuriksi. Suurimmat vauriot todettiin silloin, kun lumipeitteen kesto ja vahvuus olivat suuret ja edellisen syksyn sato oli niitetty syyskuun puolivälissä.

Ilman vakavia talvehtimisvaurioitakin korkeilla typpiannoksilla lannoitetut nurmet harvenivat, mutta sadot muodostuivat siitä huolimatta suuriksi. Eräissä tapauksissa nurmet säilyivät vielä 300 kg/ha -typpilannoituksella tyydyttävän tiheinä viisi vuotta.

ANNALES AGRICULTURAE FENNIAE, VOL. 13: 96—108 (1974)

Seria AGROGEOLOGIA ET -CHIMICA N. 68
Sarja MAA JA LANNOITUS n:o 68

EFFECTS OF HEAVY NITROGEN FERTILIZATION ON POTASSIUM, CALCIUM, MAGNESIUM AND PHOSPHORUS CONTENTS IN LEY GRASSES

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RINNE, S.-L., SILLANPÄÄ, M., HUOKUNA, E. & HIIVOLA, S.-L. 1974. **Effects of heavy nitrogen fertilization on potassium, calcium, magnesium and phosphorus contents in ley grasses.** Ann. Agric. Fenn. 13: 96—108.

The effects of 0—600 kg N/hectare/year fertilization on the potassium, calcium, magnesium and phosphorus contents of cocksfoot (*Dactylis glomerata*) and meadow fescue (*Festuca pratensis*), harvested for silage three times during the growing season, were studied at 18 experimental sites during the period 1967—1970. When nitrogen fertilization was increased, the potassium content of both plants rose sharply during the first growing season. At later stages of the experiment, when potassium resources in the soils were on the decline, this phenomenon diminished, until the third growing season, when the effect of nitrogen was reversed. The calcium and magnesium contents increased when nitrogen fertilization was increased, while phosphorus content decreased.

Introduction

The effect of nitrogen fertilization on the mineral content of grasses has been the subject of numerous studies carried out under a variety of circumstances, on different soils and using dissimilar nitrogen fertilizers. The results presented have therefore been somewhat contradictory. For example, it has generally been found that the potassium content of grasses has increased with increased N fertilization in experiments of short duration or with only moderate doses of nitrogen (SALONEN and HIIVOLA 1963, JÄNTTI and KÖYLIJÄRVI 1964, HUOKUNA 1968, RAININKO 1968, STEEN 1972).

These results contrasted with those presented e.g. by HEMINGWAY (1961) and STEEN (1968), which were derived from long-term experiments or experiments in which high nitrogen doses were used.

Several investigators assume the effect of nitrogen fertilization on potassium content to depend largely on the content of exchangeable potassium in a soil, which in turn affects the contents of other cations. Studies by JOKINEN (1969) indicate that as soil exchangeable potassium increased in relation to magnesium, magnesium content of the plants significantly decreased. 't HART (1964) found that as K content decreased in grasses, Ca, Mg and Na contents increased.

The Ca and Mg contents of plants have often been found to rise with increased nitrogen fertilization (RAININKO 1968, STEEN 1968), while the effect of nitrogen on P content has been obscure. In some cases the P content has decreased (TVEITNES 1967, HUOKUNA 1968, STEEN 1968), while the results of HEINONEN (1964) showed that nitrogen fertilization increased the phosphorus content of hay.

Most studies concerning the effect of nitrogen fertilization have been carried out under conditions where the pH of the soil has remained relatively stable. In this study the pH of soils generally decreased with increasing nitrogen fertilization. This naturally affects the availability of nutrients in soil and accordingly the results of the study.

Materials and methods

Full details of the plan of the experiment carried out at the experiment stations of the Agricultural Research Centre were given in the preceding number of this series (HUOKUNA and HIIVOLA 1974).

Plant samples from the four replicates for each treatment from each site were combined before analyses, ground and passed through a 1 mm stainless steel sieve. Ten grammes of each sample were ashed by raising the temperature slowly (6 hr.) to 450°C and maintaining this temperature overnight. The ash was dissolved to 10 ml of 6 N HCl, kept, covered, almost at boiling for half an hour and evaporated until dry. The procedure was repeated. The ash was dissolved to about 20 ml of 0.6 N HCl and filtered into a 100 ml graduate. The crucible and the insoluble remains were repeatedly washed with hot 0.6 N HCl and the graduate was filled to the 100 ml mark. For Ca determination, the solution was diluted 1 : 20 with La-solution (5 g La_2O_3 + 10 ml conc. HCl/1 000 ml H_2O). From the diluted solution, Ca, K and Mg were determined with an atomic absorption spectrophotometer. P was determined from the same solution colorimetrically (ammonium molybdatevanadate method).

Statistical analyses of the results were carried out by the Computing Service of the Agricultural Research Centre. Significances are given at 0.001***, 0.01** and 0.05* levels. The homogeneity of correlations was tested with χ^2-test (SNEDECOR and COCHRAN 1971).

Results

Average mineral content in yield D.M. for the whole material, various N treatments, three soil groups, two plants, three cuts and three years are given in Table 2 and F-values of variance analysis in Table 3. Correlations (r-values) of the contents of K, Ca, P and Mg on nitrogen fertilization are given in Table 4.

Significant differences between the mean mineral contents of the plants, soils, cuts and years were found in almost all cases. Tests of homogeneity (χ^2) between correlations show that the effect of nitrogen fertilization on K, Ca, P and Mg contents was significantly different for different soils and cuts, and on K and P contents the effects also varied in different years. Therefore, in order to give a detailed picture of the changes in the contents of these elements, regressions are listed for each cut during the three-year experimental period, for each plant separately and for the two soil groups (Tables 5—8).

When interpreting the results of this study, the considerable increases in yield due to nitrogen fertilization should not be overlooked. These were highest during the first growing season and declined toward the end of the three-year experimental period. At various nitrogen fertilization levels following average D.M. yields were obtained:

Nitrogen fertilization kg N/ha/yr	Dry matter yield kg/ha 1st yr	2nd yr	3rd yr
0	2 780	1 770	1 410
150	7 170	6 100	5 120
300	9 280	8 080	6 290
450	10 100	8 430	6 280
600	10 200	8 310	5 950

Table 1. Correlations (r-values) between the potassium content in D.M. of ley grasses and nitrogen fertilization for different soils, cuts and years.

	Coarse mineral soils			Fine mineral soils			Organogenic soils		
		Cut			Cut			Cut	
	I	II	III	I	II	III	I	II	III
1. year	.56***	.48***	.08	.57***	.62***	.48***	.86***	.60***	.28
2. ,,	.18	—.14	—.16	.52***	.30**	.38***	.12	—.02	—.83***
3. ,,	—.02	—.40***	—.54***	.18	.13	.08	.30	—.53***	—.71***

The changes caused by heavy nitrogen fertilization in many soil properties must also be borne in mind when discussing the changes in the mineral contents of plants. Part of the results of this series of experiments concerning soil properties, have recently been published (Joy, Lakanen and Sillanpää 1973), while another part, also referred to frequently in this paper, has been accepted for publication.

One soil factor worth mentioning is the pH. During the three-year period covered by this study soil pH decreased with increasing nitrogen fertilization on the average as follows: at 150—300 kg N/ha level the decline was 0.10—0.15 pH unit and at 450 and 600 kg N/ha levels 0.29 and 0.41 pH unit, respectively. These drops were sufficiently great to affect the solubility of various elements considerably.

Potassium

Nitrogen fertilization increased the K content of plants in cases where there was sufficient potassium available in the soil. For the whole material the K content increased from 2.90 to 3.33 per cent of D.M. when nitrogen fertilization was increased from 0 to 600 kg N/hectare (Table 2 and Fig. 1). Nitrogen fertilization explained 3.4 per cent of the variation in K with statistically high significance.

The effects of all factors under study (nitrogen, plant species, soils, cuts and age of ley) on the K content of the yield were highly significant. The greatest variances in K content were between different years at the highest levels of nitrogen fertilization. The general trend of correlation coefficients given in Table 1 shows that the correlations between N fertilization and K content, which in the first year are highly significant and positive, changed to highly significant negative correlations as the age of the ley increased. A similar trend appears from the first towards the third cut. These changes are most pronounced on organic and coarse mineral soils.

Soils: The average K content of plants grown on coarse mineral soils increased from 2.59 to 3.06, on fine mineral soils from 2.80 to 3.60 and on organogenic soils from 2.92 to 3.01 per cent as the annual nitrogen fertilization increased from 0 to 600 kg N/hectare (Fig. 1). The increased K content in the whole material is mainly attributable to the sharp increase found in grasses grown on fine mineral soils (Table 4), where the exchangeable K content was almost twice as high as in other soils in this study. On other soils the overall correlations were not significant, in spite of the sharp increase in K content found in the first year's first and second cuts (Tables 1 and 5). This is due to the rapid decline in soil potassium, limiting potassium uptake by plants in later stages of the experiment. A detailed study on the effects of heavy nitrogen fertilization on soil potassium reserves, based on the present material, was recently published in this series by Joy, Lakanen and Sillanpää (1973).

According to this study, the loss of soil potassium resources was over 500 kg K/ha during the three-year period of heavy nitrogen fertilization.

Plant species: In the whole study the average K content of cocksfoot, 3.36 %, was significantly higher than that of fescue, 3.05 % (Tables 2 and 3). The differences in the effect of nitrogen fertilization on the two plants were mainly in the rate at which the changes took place. The correlations between N fertili-

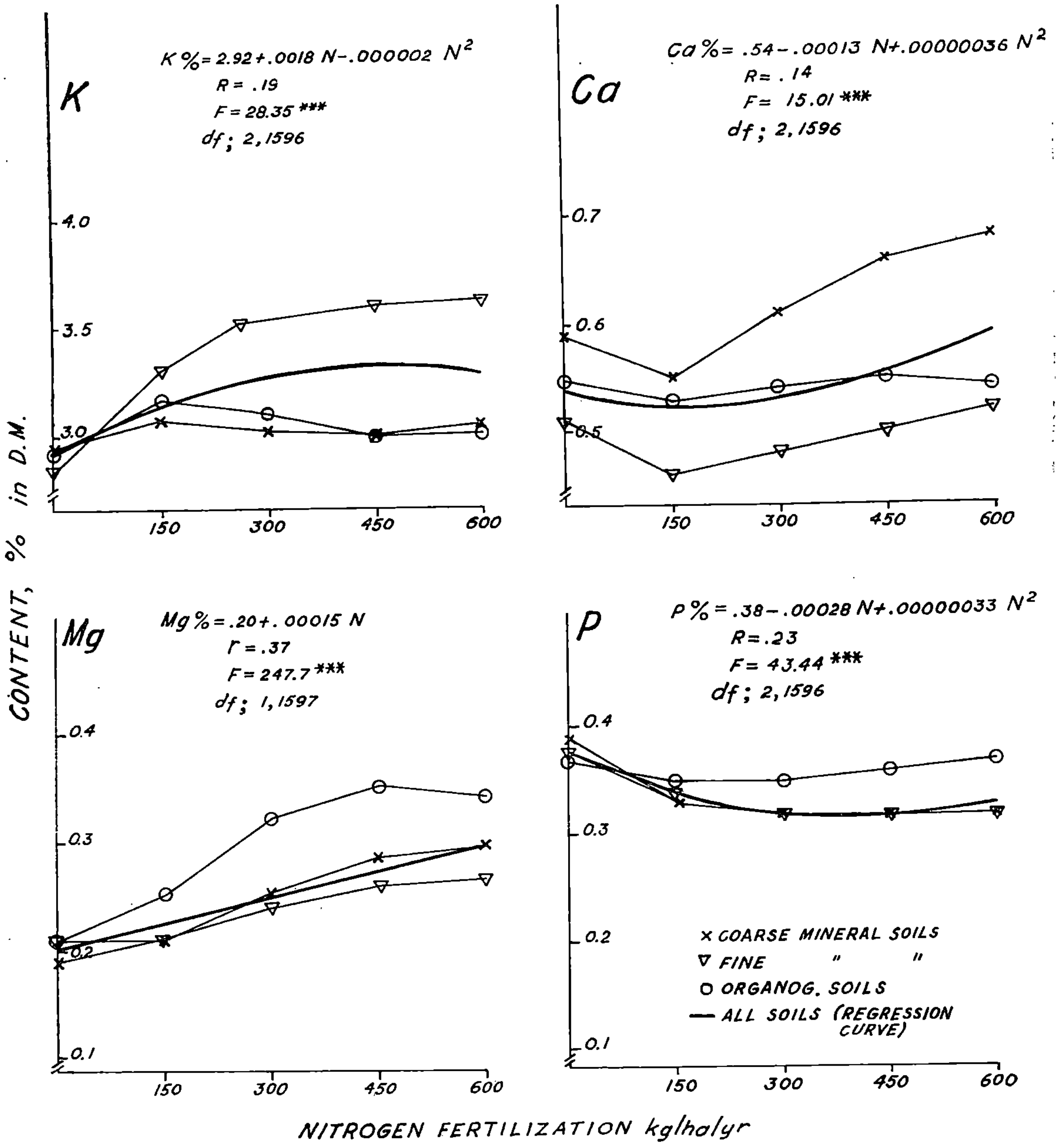

Fig. 1. Regressions (equations and curves) of K, Ca, Mg and P contents in D.M. of ley grasses on nitrogen fertilization for the whole experimental material (3 soil groups, 2 plant species, 3 cuts and 3 ley years). Broken lines indicate the average nutrient contents at various nitrogen dressing levels for the three soil groups separately.

zation and K content of fescue were, however, stronger than those of cocksfoot (Table 4). At an early stage in the experiment there was a strong trend towards increased K content due to nitrogen fertilization in both species; on fine mineral soils this trend was stronger for cocksfoot than for fescue, but on coarse mineral soils vice versa. At later stages in the experiment the tendency diminished and a decrease set in. This change took place earlier and more sharply in the case of cocksfoot than of fescue (Table 5). This is apparently due to more ef-

Table 2. Effects of nitrogen fertilization, plant species, cutting time, soils and age of ley on the K, Ca, P and Mg contents in D.M. of ley grasses. The TUKEY test (Steele and Torrie, 1960) was applied to test the differences between the averages. Values followed by the same letter do not differ significantly ($P < 0.05$) from each other.

	Number of samples	K %	Ca %	P %	Mg %
NITROGEN FERTILIZATION kg/ha/yr					
0	318	2.90^{a}	.55^{bc}	.38^{b}	.20^{a}
150	328	3.20^{b}	.51^{a}	.33^{a}	.21^{a}
300	322	3.29^{b}	.54^{ab}	.33^{a}	.25^{b}
450	316	3.30^{b}	.57^{bc}	.32^{a}	.28^{c}
600	315	3.33^{b}	.58^{c}	.33^{a}	.29^{c}
SOILS					
Coarse mineral soils	617	3.03^{a}	.62^{c}	.34^{a}	.25^{a}
Fine mineral soils	805	3.37^{b}	.50^{a}	.33^{a}	.24^{a}
Organogenic soils	177	3.04^{a}	.54^{b}	.36^{b}	.29^{b}
SPECIES					
Meadow fescue	800	3.05^{a}	.62^{b}	.34^{a}	.25^{b}
Cocksfoot	799	3.36^{b}	.47^{a}	.34^{a}	.24^{a}
CUT no.					
I	528	3.55^{b}	.46^{a}	.34^{b}	.18^{a}
II	530	3.01^{a}	.57^{b}	.30^{a}	.26^{b}
III—IV [1]	541	3.06^{a}	.62^{c}	.37^{c}	.30^{c}
AGE of the ley years					
1	560	3.62^{c}	.51^{a}	.33^{a}	.23^{a}
2	533	3.11^{b}	.55^{b}	.34^{a}	.25^{b}
3	506	2.83^{a}	.58^{c}	.35^{a}	.26^{b}
Average for whole material	1599	3.20	.55	.34	.25
Standard deviation		±0.83	±.17	±.09	±.09

[1] Cut IV was made at two sites only.

fective uptake of soil K by cocksfoot (higher K content) thus exhausting the soil K reserves more rapidly than fescue (Joy, Lakanen and Sillanpää 1973).

Cutting time: On the average, the highest K content (3.55 %) was found in the grass of the first cut, and the lowest (3.01 %) in the second cut (Tables 2 and 3). The effect of nitrogen fertilization on K content was also greatest in grass of the first cut: The positive correlation between nitrogen and K content was highly significant in the first cut, but no longer significant in the third cut (Fig. 2). This is apparently due to the fact that the entire annual dose of potassium fertilizer (100 kg K/ha) was applied in the spring.

In the first year of the experiment a strong trend towards increased K content in grass as nitrogen fertilization increased was obvious, regardless of soils (Tables 1 and 5). On fine mineral soils, this trend prevailed into the second and third years, even though there was no sig-

Table 3. F-values for mineral contents.

	K	Ca	P	Mg
Nitrogen fertilization	14.8***	9.8***	23.4***	65.2***
Soils	35.4***	100.1***	7.5***	34.0***
Species	59.0***	364.2***	0.3	4.4*
Cutting time	75.1***	149.4***	71.3***	351.7***
Age of the ley	148.4***	22.1***	2.8	20.6***

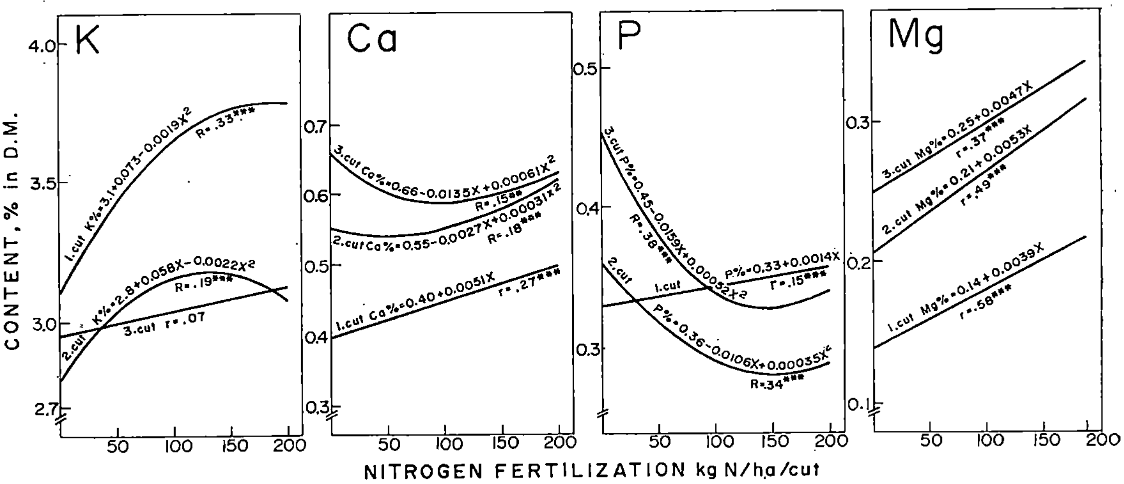

Fig. 2. Regressions of K, Ca, P and Mg contents on nitrogen fertilization for the three cuts (all soils, plants and years). X = N × 10¹⁻kg/ha/cut

nificance in the correlations of the third year. On coarse mineral soils and on organogenic soils the K content decreased significantly in the grasses of the two later cuts.

Age of the ley: The average annual K content of the grass decreased from 3.62 per cent in the first year to 2.83 per cent in the third year (Tables 2 and 3). This significant decrease, as explained above, is obviously due to the diminishing supply of soil potassium caused by nitrogen-stimulated potassium uptake. The correlation coefficients for K (Table 4), given separately for the two plant species and the three years, support the above hypothesis.

Calcium

As the nitrogen fertilization applied in the form of Oulu saltpetre (cont. 6 % Ca) increased from 150 to 600 kg N/ha (35 to 140 kg Ca/ha), the Ca content of grass D.M. increased from 0.51 to 0.58 per cent on the average (Tables 2 and 3). The Ca content of the control, however, was higher than that in plots which received the lowest doses of nitrogen (Fig. 1). Only 1.8 % of the variation in Ca content was due to nitrogen. In the Ca content/nitrogen fertilization correlations there were significant differences between the three soil groups as well as between the three cuts (Table 4). The regressions of Ca content on nitrogen fertilization are given separately in Table 6 for each yield on two soil groups.

Soils: The average Ca content was highest (0.62 per cent) in the grass grown on coarse mineral soils and lowest (0.50 per cent) on fine mineral soils (Tables 2 and 3). Significant differences existed between the correlations for various soils (Table 4, χ^2).

Increasing nitrogen fertilization increased the Ca content significantly on coarse mineral soils. On organogenic soils the increase was not statistically significant. On fine mineral soils even negative Ca content/nitrogen fertilization correlations were obtained from the autumn cuts (Table 6).

Plant species: The greatest variation in Ca content was due to the big differences between the two species. The average Ca content of fescue, 0.62 per cent, was significantly higher than that of cocksfoot, 0.47 per cent (Tables 2 and 3). Increasing nitrogen fertilization significantly increased the Ca content of fescue (r = 0.23***), while the relationship remained insignificant in the case of cocksfoot (Table 4). This may be due to the two-way effect of nitro-

Table 4. Correlations (r-values) between the contents of the four elements and nitrogen fertilization and differences in homogeneity (χ^2) between the correlations.

	K	Ca	P	Mg
	Meadow fescue			
SOILS				
Coarse mineral soils	.10	.35***	—.10	.51***
Fine mineral soils	.40***	.17***	—.08	.36***
Organogenic soils	.07	.16	.07	.48***
Sign. of diff., χ^2	***	*	ns	*
CUTS				
I	.42***	.44***	.30***	.60***
II	.23***	.35***	—.13*	.55***
III	.14*	.02	—.26***	.42***
Sign. of diff., χ^2	***	***	***	*
AGE, YEARS				
1	.51***	.17**	.13*	.40***
2	.24***	.31***	—.10	.44***
3	—.04	.19**	—.25***	.47***
Sign. of diff., χ^2	***	ns	***	ns
Averages for meadow fescue	.24***	.23***	—.06	.42***
	Cocksfoot			
SOILS				
Coarse mineral soils	—.03	.12*	—.37***	.40***
Fine mineral soils	.26***	—.07	—.31***	.22***
Organogenic soils	—.06	—.12	—.07	.38***
Sign. of diff., χ^2	***	*	*	*
CUTS				
I	.26***	.22***	—.01	.56***
II	.07	—.02	—.42***	.41***
III	.01	—.11	—.38***	.30***
Sign. of diff., χ^2	*	***	***	**
AGE, YEARS				
1	.40***	—.06	—.14*	.24***
2	.00	.08	—.34***	.31***
3	—.14	.02	—.38***	.39***
Sign. of diff., χ^2	***	ns	**	ns
Averages for cocksfoot	.10***	.01	—.29***	.30***

gen (depending on cut) in fine mineral soils (Table 6).

Cutting time: The average Ca content of D.M. generally increased toward the autumn. The contents were 0.46, 0.57 and 0.62 per cent in the Ist, IInd and IIIrd cuts, respectively. Nitrogen fertilization increased the Ca content of the grass from the first cut highly significantly. In the third cut, when the Ca content was highest, nitrogen diminished it in most cases (Fig. 2, Table 6).

Age of the ley: The average Ca content of the grasses increased as the age of the ley increased (Tables 2 and 3). The increasing effect of nitrogen fertilization on Ca content was most pronounced in the second growing season. However, no significant differences existed in the nitrogen fertilization/Ca content correlations between different years (Table 4).

Phosphorus

As nitrogen fertilization increased from 0 to 600 kg N/ha, the P content of grasses decreased significantly from 0.38 to 0.33 per cent on the average (Tables 2 and 3, Fig. 1). Highest P contents were found in grasses grown on plots without nitrogen dressing.

Table 5. Regressions of K content on nitrogen fertilization. Equations: $y = a + bx$ or $y = a + bx + cx^2$, where y = K content (%), a = constant (%), b and c = regression coefficients and $x = N \times 10^{-1}$kg/ha/cut.

Age years	Cut no.	POTASSIUM, % in D.M.											
		MEADOW FESCUE						COCKSFOOT					
		a	b	r	c	R	df	a	b	r	c	R	df
		Coarse mineral soils											
1	I	3.1	.063	.72***			1,33	3.7	.057	.49**			1,33
	II	2.8	.057	.59***			1,33	3.2	.036	.37*			1,33
	III	2.9	.021	.21			1,33	3.2	—.009	—.09			1,33
2	I	2.7	.021	.28			1,33	3.2	.012	.13			1,33
	II	2.6	—.006	—.08			1,33	2.9	—.021	—.19			1,33
	III	2.9	—.006	—.06			1,32	3.3	—.036	—.24			1,32
3	I	3.0	.003	.07			1,29	3.3	—.009	.09			1,29
	II	2.8	—.036	—.46**			1,30	2.9	—.042	—.38*			1,30
	III	2.6	—.039	—.51**			1,29	2.8	—.057	—.57***			1,29
		Fine mineral soils											
1	I	3.2	.057	.70***			1,43	3.9	.063	.61***			1,43
	II	2.4	.114		—.0036	.72***	2,42	2.8	.129		—.0036	.77***	2,42
	III	2.8	.072	.48***			1,43	3.1	.072	.47**			1,43
2	I	2.9	.054	.69***			1,43	3.4	.087		—.0036	.49**	2,42
	II	2.3	.120		—.0045	.62***	2,42	3.2	.015	.17			1,43
	III	2.6	.039	.48**			1,38	3.1	.024	.24			1,38
3	I	2.9	.027	.37*			1,41	3.5	.001	.02			1,41
	II	2.3	.084		—.0036	.39*	2,40	3.1	.006	.07			1,41
	III	2.5	.018	.19			1,40	3.0	—.001	—.01			1,41

Table 6. Regressions of Ca content on nitrogen fertilization. Equations: $y = a + bx$ or $y = a + bx + cx^2$, where y = Ca content (%), a = constant (%), b and c = regression coefficients and $x = N \times 10^{-1}$kg/ha/cut.

Age years	Cut no.	CALCIUM, % in D.M.											
		MEADOW FESCUE						COCKSFOOT					
		a	b	r	c	R	df	a	b	r	c	R	df
		Coarse mineral soils											
1	I	.52	.0075	.41*			1,33	.33	.0036	.40*			1,33
	II	.63	.0069	.44**			1,33	.52	.0021	.14			1,33
	III	.65	.0030	.13			1,33	.53	—.0009	—.04			1,33
2	I	.46	.0111	.64***			1,33	.36	.0075	.51**			1,33
	II	.59	.0165	.66***			1,33	.54	.0024	.10			1,33
	III	.72	.0078	.29			1,32	.62	.0012	.04			1.32
3	I	.50	.0096	.52**			1,30	.41	.0081	.47**			1,29
	II	.67	.0084	.39*			1,29	.63	.0012	.06			1,29
	III	.78	.0036	.20			1,29	.70	.0015	.08			1,29
		Fine mineral soils											
1	I	.44	.0042	.56***			1,43	.30	.0018	.33*			1,43
	II	.53	.0039	.25			1,43	.50	—.0153		.00063	.54***	2,42
	III	.64	—.0012	—.07			1,43	.51	—.0237		.00090	.51**	2,42
2	I	.43	.0069	.56***			1,43	.25	.0066	.73***			1,43
	II	.50	.0087	.45**			1,43	.43	.0006	.04			1,43
	III	.75	—.0273		—.0009	.46*	2,37	.62	—.0345		.00135	.72***	2,37
3	I	.46	.0036	.36*			1,41	.34	.0021	.17			1.41
	II	.51	.0078	.42**			1,41	.48	—.0012	—.09			1,41
	III	.71	—.0042	—.20			1,40	.58	—.0039	—.19			1,41

Table 7. Regressions of P content on nitrogen fertilization. Equations: $y = a + bx$ or $y = a + bx + cx^2$, where y = P content (%), a = constant (%), b and c = regression coefficients and $x = N \times 10^{-1}$kg/ha/cut.

Age years	Cut no.	PHOSPHORUS, % in D.M.											
		MEADOW FESCUE						COCKSFOOT					
		a	b	r	c	R	df	a	b	r	c	R	df
		Coarse mineral soils											
1	I	.28	.0057	.49**			1,33	.28	.0024	.22			1,33
	II	.27	.0018	.21			1,33	.37	—.0126		.00045	.50**	2,32
	III	.38	—.0021	—.22			1,33	.47	—.0189		.00063	.56**	2,32
2	I	.30	.0018	.30			1,33	.32	—.0015	—.02			1,33
	II	.33	—.0024	—.33			1,33	.43	—.0234		.00081	.76***	2,32
	III	.45	—.0054	—.34*			1,32	.55	—.0291		.00099	.67***	2,31
3	I	.35	—.0003	—.05			1,30	.35	—.0015	—.17			1,29
	II	.37	—.0036	—.48**			1,30	.47	—.0246		.00081	.64***	2,29
	III	.45	—.0180		.00063	.76***	2,28	.51	—.0321		.00108	.85***	2,28
		Fine mineral soils											
1	I	.32	.0045	.56***			1,43	.34	.0012	.17			1,43
	II	.26	.0003	.07			1,43	.31	—.0039	—.37*			1.43
	III	.38	—.0024	—.15			1,43	.37	—.0018	—.13			1,42
2	I	.32	.0033	.35*			1,43	.34	—.0003	—.03			1,43
	II	.32	—.0009	—.10			1,43	.42	—.0192		.00063	.61***	2,42
	III	.39	—.0063	—.42**			1,38	.52	—.0372		.00126	.64***	2,37
3	I	.34	.0009	.09			1,41	.36	—.0015	—.15			1,41
	II	.32	—.0033	—.32*			1,41	.41	—.0198		.00063	.54**	2,40
	III	.40	—.0057	—.39*			1,40	.47	—.0228		.00072	.54**	2,40

The average differences in P contents due to varying doses of nitrogen were negligible. In the effects of nitrogen, however, significant differences existed between the plant species, soils, cuttings and years (Tables 4 and 7).

Soils: Differences in P contents of grasses grown on different soils were relatively small but statistically significant (Tables 2 and 3). Correlations between P content of grasses grown on different soils and nitrogen fertilization were heterogeneous. Only for cocksfoot grown on mineral soils were the diminishing effects of nitrogen on P content statistically significant, while on organogenic soils these relationships remained obscure (Table 4).

Plant species did not differ from each other in their average P content (Tables 2 and 3). However, the decrease in P content as a function of nitrogen was significant ($r = -0.29^{***}$) only for cocksfoot (Table 4), where the P content (without N) was originally higher than in fescue (Table 7).

Cutting time: On the average P content of grasses was lowest (0.30 per cent) in the second and highest (0.37 per cent) in the third harvest (Table 2). Nitrogen fertilization increased the P content of the grass cut first ($r = 0.15^{***}$) but more than compensated for this increase by the decrease in grasses of the later cuts ($R = 0.34^{***}$ and 0.38^{***}; Fig. 2).

On the average, age of the ley had no significant effect on the P content of grasses (Tables 2 and 3). The decreasing effect of nitrogen fertilization on the P content became increasingly evident, however, toward the end of the experimental period (Table 4). This was apparently due to the decreasing availability of soil phosphorus caused by the reduction in soil pH (unpublished data).

Magnesium

Nitrogen fertilization, given in the form of Oulu saltpetre (cont. 3 per cent

Table 8. Regressions of Mg content on nitrogen fertilization. Equation: y = a + bx, where y = Mg content (%), a = constant (%), b = regression coefficients and x = N fertilization N × 10^{-1}kg/ha/cut.

Age years	Cut. no.	MAGNESIUM % in D.M.							
		MEADOW FESCUE				COCKSFOOT			
		a	b	r	df	a	b	r	df
		Coarse mineral soils							
1	I	.12	.0042	.75***	1,33	.13	.0033	.66***	1,33
	II	.16	.0069	.71***	1,33	.19	.0033	.46**	1,33
	III	.21	.0063	.49**	1,33	.23	.0027	.35*	1,33
2	I	.13	.0057	.81***	1,33	.13	.0036	.69***	1,33
	II	.18	.0099	.67***	1,33	.19	.0048	.52**	1,33
	III	.24	.0090	.52**	1,32	.25	.0048	.39*	1,32
3	I	.14	.0063	.78***	1,30	.14	.0057	.86***	1,29
	II	.20	.0087	.65***	1,29	.21	.0054	.59***	1,30
	III	.25	.0090	.70***	1,29	.25	.0072	.65***	1,29
		Fine mineral soils							
1	I	.15	.0030	.49***	1,43	.15	.0024	.60***	1,43
	II	.20	.0033	.32*	1,43	.24	.0018	.24	1,43
	III	.24	.0021	.29	1,43	.26	—.0006	—.09	1,43
2	I	.15	.0030	.53***	1,43	.14	.0018	.64***	1,43
	II	.19	.0078	.60***	1,43	.23	.0030	.44**	1,43
	III	.27	.0024	.26	1,38	.28	.0006	.07	1,38
3	I	.15	.0036	.46**	1,41	.15	.0030	.51***	1,41
	II	.19	.0060	.53***	1,41	.23	.0030	.35*	1,41
	III	.24	.0048	.45**	1,40	.26	.0027	.33*	1,41

Mg), increased the Mg content of the yields significantly. On the average, the content of Mg at 0 level of nitrogen fertilization was 0.20 per cent of D.M. and at 600 kg N/ha level 0.29 per cent (Tables 2 and 3, Fig. 1). Of the variation in Mg content, 13.4 per cent was due to fertilization. The correlations between Mg content and fertilization were significantly different between cuts as well as between soil groups, while no significant difference existed between the years (Table 4).

Soils: The average Mg content was highest on grasses grown on organogenic soils (0.29 %) and lowest on fine mineral soils (0.24 %) (Tables 2 and 3, Fig. 1). On coarse mineral soils fertilization increased the content of Mg in D.M. from 0.19 to 0.29 per cent, on fine mineral soils from 0.21 to 0.27 and on organogenic soils from 0.21 to 0.34 per cent. These increases were all highly significant statistically (Table 4).

Plant species differed slightly, but significantly from each other. The average Mg contents of cocksfoot and fescue were 0.24 and 0.25 per cent, respectively. The effect of fertilization, however, was greater on Mg content of fescue than on that of cocksfoot (Tables 4 and 8).

Cutting time caused significant differences in the Mg content (Tables 2 and 3). On the average, the Mg content increased from the first cut (0.18 per cent) toward the third cut (0.30 per cent), while there were no essential differences in the increasing effect of fertilization on Mg content between the cuts (Fig. 2).

Age of the ley: On the average the Mg content in D.M. increased significantly while yields decreased simultaneously toward the end of the experimental period (Tables 2 and 3). The increasing effect of fertilization on Mg content increased with the years (Table 8). Also the content of soil exchangeable Mg increased due to nitrogen fertilizer containing Mg (unpublished data).

Discussion

It is obvious that extremely high doses of fertilizers, especially nitrogen, can disturb the balance between nutrients native to the soil, both directly and through other changes in soil properties, such as pH. These changes are, in turn, likely to be reflected in the yields, nutrient uptake and nutrient contents of plants. When interpreting the results of this study it should also be borne in mind that other nutrients besides nitrogen were given in fertilizers. Thus, the nitrogen fertilizer given contained 26 % N, 6 % Ca and 3 % Mg and the standard fertilization given to all plots included 100 kg K, 44 kg P and 100 kg Ca per hectare.

In spite of relatively high potassium fertilization (300 kg K/ha/3 years) soils in all plots which received nitrogen showed negative K balances (fertilizer K minus K uptake), while the corresponding balances for P, Ca and Mg were positive.

The K content of grasses increased strongly when nitrogen dressing increased as long as there was sufficient potassium available in soils. This was most evident in the first year and in grasses of the first cut. There was more native soil potassium available in the first year than in later years and more fertilizer potassium available for the grasses cut first than at later stages during the growing season. This was because the whole potassium dressing was applied in the spring. The decreasing K contents in grasses toward the end of the experimental period as well as toward the end of each growing season indicate increasing limitations in K uptake by plants. This is supported by the soil analyses made before and after the three-year experimental period (Joy, Lakanen and Sillanpää 1973). For example, with a nitrogen dressing level of 450 kg N/ha, the total K uptake by the yields was 820 kg K/ha, 300 kg K of which was replaced in the soil by K fertilization. The difference, 520 kg K/ha, indicates the total loss of native soil K sources during the period.

A contributory cause of the increased Ca and Mg contents of grasses with increasing nitrogen fertilization was that the nitrogen fertilizer also contained these nutrients. These increases seem, however, to depend on soil types. The average contents of Ca and Mg were higher and the increases due to fertilization were stronger in grasses grown on coarse mineral soils than on fine mineral soils; in spite of this, in the latter soils the original soil exchangeable Ca and Mg contents were about twice as high as in coarse mineral soils (unpublished data).

As the uptake of K by plants is many times greater than that of Ca and Mg, it is possible that the dominating K uptake limits the uptake of Ca and Mg. This seems to be the case on fine mineral soils, where K is more dominant than on other soils. This kind of antagonism has been reported by other investigators. E.g. Reith et al. (1964) found that potassium decreased the Mg content and nitrogen increased it in conditions where there was a deficiency of potassium. This phenomenon may also partly explain the lower Ca and Mg contents of grasses from the first cut compared with the later cuts.

A comparison between the two plant species indicates a similar tendency. Cocksfoot had a high content of K but low contents of Ca and Mg, while fescue, with significantly lower K content, had significantly higher Ca and Mg contents.

Similarly, whereas K content decreased from the first to the third year, the Ca and Mg contents had a tendency to increase. It seems apparent, therefore, that in this study the contents of exchangeable potassium in soils or, indirectly, the soil types, were among the most important factors affecting the uptake and relationships between these cations.

The solubility of soil phosphorus and its availability to plants depends essentially on soil pH. Therefore, the decrease in soil pH apparent with increasing nitrogen fertilization decreased the availability of P and, consequently, its content in plants despite the substantial P dressing (unpublished data). However, the increasing P contents found in grasses of the first cut as nitrogen dressing increased constituted an exception. This may be due to the gradual fixation of fertilizer phosphorus (Sillanpää 1961), rendering the phosphorus applied in spring was more readily available for grasses of the first than of the later cuts. The low P content in summer grasses and the high content in the autumn cuts may be associated with the changes in soil moisture relationships and in pH during the growing season ('t Hart 1964).

The increase in the average P content in grasses over the years may be a consequence of overdoses of P fertilizer, while the more marked negative correlations between the P content and N fertilization toward the end of the experimental period is apparently due to the reduced soil pH caused by nitrogen fertilization.

REFERENCES

Hart, M. L.'t 1964. Innehållet av olika kemiska komponenter i gräs vid intensiv betesskötsel. Nord. Jordbr.-forskn. Suppl. 9: 665—675.

Heinonen, H. 1964. Wirkung von Niederschlag und Temperatur auf den Mineralstoffgehalt des Timotheeheus. Ann. Agric. Fenn. 3: 55—67.

Hemingway, R. G. 1961. Magnesium, potassium, sodium and calcium contents of herbage as influenced by fertilizer treatments over a three year period. J. Brit. Grassl. Soc. 16: 106—116.

Huokuna, E. 1968. Lypsykarjan laitumen runsas typpilannoitus. Summary: Heavy dressing of nitrogen fertilizing on pasture of milking cows. Ann. Agric. Fenn. 7: 25—32.

— & Hiivola, S-L. 1974. The effect of heavy nitrogen fertilization on sward density and winter survival of grasses. Ann. Agric. Fenn. 13: 88—95.

Jokinen, R. 1969. The magnesium status of soil and the magnesium content of cultivated plants. J. Sci. Agric. Soc. Finl. 41: 290—297.

Joy, P., Lakanen, E. & Sillanpää, M. 1973. Effects of heavy nitrogen dressings upon release of potassium from soils cropped with ley grasses. Ann. Agric. Fenn. 12: 172—184.

Jäntti, A. & Köylijärvi, J. 1964. Laidunnurmien typpiväkilannoituskokeiden tuloksia. Summary: Results of nitrogen fertilization on pasture. Ann. Agric. Fenn. 3: 165—214.

Raininko, K. 1968. The effects of nitrogen fertilization, irrigation and number of harvestings upon leys established with various seed mixtures. Acta Agr. Fenn. 112: 1—137.

Reith, J. W. S., Inkson, R. H. E., Holmes, W. et al. 1964. The effects of fertilizers on herbage production. II. The effect of nitrogen, phosphorus and potassium on botanical and chemical composition. J. Agric. Sci. 63: 209—219.

Salonen, M. & Hiivola, S-L. 1963. Typpilannoituksen vaikutus puna-apilan ja nurminadan sadon määrään ja laatuun. Summary: The effect of nitrogen fertilization on the yield and quality of the crop of red clover and meadow fescue. Ann. Agric. Fenn. 2: 136—152.

Sillanpää, M. 1961. Fixation of fertilizer phosphorus as a function of time in four Finnish soils. Agrogeol. Publ. 80: 1—22.

Snedecor, G. W. & Cochran, W. G. 1971. Statistical methods. 593 p. Ames, Iowa.

Steele, R. G. & Torrie, J. H. 1960. Principles and procedures of statistics. 481 p. New York.

Steen, E. 1968. Inverkan av kvävegödsling på kvaliteten hos fyra vallgräs på betesstadiet. Summary: Influence of nitrogen fertilization on the quality of four grasses at the grazing stage. Lantbr.högsk. Medd. A 92: 1—27.

— 1972. Stigande mängder kväve till fem vallgräsarter skördade tre gånger per säsong. Summary: Increasing amounts of nitrogen to five grass species cut three times per season. Lantbr.högsk. Medd. A 176: 1—43.

Tveitnes, S. 1967. Forsøk med stigande mengder nitrogen till eng. Summary: Field trials with increasing rates of nitrogen to grassland. Forskn. Fors. Landbr. 18: 23—39.

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SELOSTUS

Runsaan typpilannoituksen vaikutus säilörehunurmen kalium-, kalsium-, magnesium- ja fosforipitoisuuteen

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Maatalouden tutkimuskeskus

Typpilannoituksen (0—600 kg/N/ha/v) vaikutusta säilörehuasteella niitetyn nurminadan ja koiranheinän kivennäisainepitoisuuteen tutkittiin kolmen vuoden ajan 18 koepaikalla eri puolilla maata yhteensä 1 599 näytteestä, joista jokainen oli yhdistetty neljästä kerrannenäytteestä. Typpi annettiin Oulunsalpietarina kolmena eränä kasvukaudella ja peruslannoitus keväisin (200 kg K_{60} ja 500 kg superfosfaattia hehtaarille).

Typpilannoitus nosti tilastollisesti erittäin merkitsevästi sadon kaliumpitoisuutta kokeen alussa ja kesän ensimmäisissä sadoissa, mutta myöhemmin maan kaliumvarastojen vähennyttyä pitoisuus sadoissa laski erittäin merkitsevästi typpitason noustessa (taul. 1 ja 5, kuva 2). Oulunsalpietarilannoitus lisäsi merkitsevästi sadon magnesium- ($r = 0.37^{***}$) ja kalsiumpitoisuutta ($R = 0.14^{***}$, kuva 1), fosforipitoisuutta lannoitus sen sijaan keskimäärin koko aineistossa laski. Aleneminen oli kuitenkin merkitsevä vain pelkän PK-lannoituksen ja pienimmän typpimäärän saaneen koejäsenen välillä (taul. 2, kuva 1).

Typpilannoitus selitti kuitenkin kivennäispitoisuuksien vaihteluista vain vähän, joskin kaikissa tapauksissa tilastollisesti erittäin merkitsevästi. Suuria vaihteluita aiheuttivat niittokertojen, kasvilajien, maalajien ja vuosien väliset tasoerot kivennäisainepitoisuuksissa sekä erot typen vaikutuksessa.

Kokeessa tuli selvästi esille maalajin voimakas vaikutus sadon kivennäispitoisuuksiin. Hienoilla kivennäismailla sadon kaliumpitoisuus oli korkea ja typpilannoitus lisäsi sitä koko kokeen ajan. Karkeilla ja eloperäisillä mailla sen sijaan jo toisena koevuotena typen vaikutus oli negatiivinen (taul. 1) ja sadon K-pitoisuus laski useissa tapauksissa alle 2 %:n. Sadon kalsium- ja magnesiumpitoisuudet taas nousivat typpitason noustessa jyrkemmin karkeilla kivennäismailla kuin hienoilla (taul. 6 ja 8).

Myös kasvilajien välillä oli erittäin merkitseviä eroja. Koiranheinän keskimääräinen kaliumpitoisuus oli merkitsevästi korkeampi kuin nurminadan, mikä johti maan kaliumvaraston nopeampaan vähenemiseen ja koiranheinän K-pitoisuuden aikaisempaan alenemiseen typpitason noustessa (taul. 5). Koiranheinälle oli korkean K-pitoisuuden ohella tyypillistä muiden kationien, kalsiumin ja magnesiumin alhainen määrä verrattuna nurminataan (taul. 2). Kasvilajien välistä eroa tehosti usein se, että lannoitus nosti yhtenäisemmin ja jyrkemmin nurminadan kalsium- ja magnesiumpitoisuutta kuin koiranheinän (taul. 4, 6 ja 8). Fosforipitoisuudessa keskimäärin ei kasvilajien välillä ollut merkitsevää eroa, mutta typpilannoitus alensi merkitsevästi vain koiranheinän P-pitoisuutta ($r = -.29^{***}$), joka lannoittamattomana ($N=0$) oli usein huomattavasti korkeampi kuin nurminadan (taul. 7).

Kaliumpitoisuus oli korkea ja Ca- sekä Mg-pitoisuudet olivat alhaiset kesän ensimmäisissä sadoissa, syksyllä päinvastoin (taul. 2). Typpilannoitus nosti K- ja Ca-pitoisuutta selvimmin alkukesästä, kun taas loppukesästä sen vaikutus joko ei ollut merkitsevä tai oli jopa merkitsevästi negatiivinen (kuva 2, taul. 5 ja 6). Lannoituksen vaikutuksessa sadon Mg-pitoisuuteen ei ollut oleellista eroa niittokertojen välillä: typpitason noustessa Mg-pitoisuus nousi erittäin merkitsevästi jokaisella niittokerralla (kuva 2). Sadon keskimääräinen fosforipitoisuus oli eri niittokertojen sadoissa suunnilleen samaa tasoa, sen sijaan lannoituksen vaikutus vaihteli kasvukaudella. Koko aineistossa lannoituksen vaikutus oli negatiivinen, mutta useimmissa kesän ensimmäisissä sadoissa fosforipitoisuus nousi merkitsevästi typpitason noustessa (kuva 2, taul. 7).

Nurmen iän kasvaessa keskimääräinen kaliumpitoisuus sadossa laski, kun taas kalsium- ja magnesiumpitoisuudet nousivat. Runsaan fosforilannoituksen johdosta myös sadon keskimääräinen P-pitoisuus nousi huolimatta lannoituksen ja P-pitoisuuden välisen negatiivisen korrelaation voimistumisesta (taul. 2, 4 ja 7).

ANNALES AGRICULTURAE FENNIAE, VOL. 13: 109—118 (1974)

Seria AGROGEOLOGIA ET -CHIMICA N. 69
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EFFECTS OF HEAVY NITROGEN FERTILIZATION ON IRON, MANGANESE, SODIUM, ZINC, COPPER, STRONTIUM, MOLYBDENUM AND COBALT CONTENTS IN LEY GRASSES

Sirkka-Liisa Rinne, Mikko Sillanpää, Erkki Huokuna and Sirkka-Liisa Hiivola

Rinne, S.-L., Sillanpää, M., Huokuna, E. & Hiivola, S.-L. 1974. **Effects of heavy nitrogen fertilization on iron, manganese, sodium, zinc, copper, strontium, molybdenum and cobalt contents in ley grasses.** Ann. Agric. Fenn. 13: 109—118.

The effects of 0—600 kg N/hectare/year fertilization on the iron, manganese, sodium, zinc, copper, strontium, molybdenum and cobalt contents of meadow fescue (*Festuca pratensis*) and cocksfoot (*Dactylis glomerata*), harvested for silage three times during the growing season, were studied at 18 experimental sites during the period 1967—1970. The sodium, zinc and copper contents increased with increasing nitrogen fertilization and yields. The effect of fertilization on the strontium and cobalt contents was negligible while manganese, iron and molybdenum contents decreased. A decrease in soil pH during the experimental period was recorded on plots receiving high doses of nitrogen.

INTRODUCTION

It is obvious that the magnitude and even the course of the effect of nitrogen fertilization on the mineral content of plants may largely depend on several factors such as the rate and type of nitrogen fertilizer used, soil type and pH, supplies and relationships of other nutrients in soils as well as other fertilizers or lime applied with the nitrogen. For this reason differing results may be obtained from studies carried out under dissimilar conditions. Indirect effects of nitrogen due to several of the above factors on the K, Ca, Mg and P contents of ley grasses were recently demonstrated by the present authors (Rinne et al. 1974).

The effect of nitrogen fertilization on the mineral content of plants has usually been studied under conditions where the pH of soils has remained relatively stable. The Cu and Zn contents have been shown to increase with increasing nitrogen fertilization, while those of Mn, Mo and Co have been found to decrease (Hemingway 1962, Reith and Mitchell 1964, Raininko 1968). The availability of trace elements to plants depends largely, however, on the pH of soils. Mo is particularly susceptible to differences in soil pH, becoming increasingly available as the soil pH increases. The availability of Mn, Fe, Cu, Zn and Co to plants is, on the other hand, favoured by acid conditions. For example, in the experiments reported by Whitehead (1966) nitrogen fertilization decreased the Mn and Fe contents of the yield, which he assumed to be due to the rise in pH.

In the present study the pH of the soils decreased toward the end of the three-year experimental period, the decrease being most pronounced in plots which received the highest dressings of nitrogen. This naturally affects the availability of the nutrients in soil and consequently their uptake and contents in plants.

MATERIALS AND METHODS

The plan of the experiment carried out at the experiment stations of the Agricultural Research Centre as well as the methods for preparing samples (6 396) for chemical analysis were described in detail in the preceding numbers of this series (Huokuna and Hiivola 1974, Rinne et al. 1974).

Na, Fe, Mn, Zn, Cu and Sr content in D.M. were determined using an atomic absorption spectrophotometer. Mo and Co were analyzed from 90 combined samples only (5 N treatments × 3 soil groups × 2 plants × 3 years). When preparing the samples (20 g) for Mo and Co analyses the procedure was the same as for other elements, except that HF was used in releasing silicate-bound trace elements from the remainder as follows: the insoluble remainder was burned at 600—700 °C for 90 minutes, cooled, weighed, transferred to a platinum crucible and moistened with a few drops of $HClO_4$. Ten ml of HF per each 0.5 gr of the remainder was added and evaporated until dry. After the removal of silica, the remaining trace elements were dissolved to 10—20 ml of 0.1 *N* HCl and added to the solution to be analyzed (before filling up to 200 ml mark). Mo was determined colorimetrically with Zn dithiole. Co was concentrated before analysis extracting it as pyrrolidinedithiocarbamate to methylisobutylketone (MIBK, distilled at 115—116 °C) as follows: 100 ml of the solution to be analyzed was transferred with a pipette to a 200 ml graduate; 2.5 ml of 0.5 *M* NaPDTC was added and mixed; 5 ml of MIBK was added and shaken for two minutes. Deionized water was added (to 200 ml mark). After 15 minutes the ketone layer which had risen to the surface was transferred with a pipette to a graduated 10 ml test tube. The tube was filled with MIBK and centrifuged. Co was determined with an atomic absorption spectrophotometer.

The statistical analyses of the results were carried out by the Computing Service of the Agricultural Research Centre. Significances are given at 0.001***, 0.01** and 0.05* levels. The homogeneity of correlations was tested with the χ^2-test (Snedecor and Cochran 1971).

RESULTS AND DISCUSSION

Average mineral contents in yield D.M. for the whole material, various N treatments, three soil groups, two plants, three cuts and three years are given in Table 1 and F-values of variance analysis in Table 2. Correlations (r-values) of the contents of Fe, Mn, Na, Zn, Cu, Sr, Mo and Co on nitrogen fertilization are given in Table 3.

Significant differences between the mineral contents for the plants, soils, cuts and years were found in almost all cases. Homogeneity tests (χ^2) between correlations show that the effect of nitrogen fertilization on eight trace nutrients was rather homogenous between different plants, soils, cuts and years (Table 3).

Therefore, regressions concerning these nutrients and nitrogen fertilization are given only for the whole material (Figs. 1 and 2) and for different cuts (Fig. 3).

When interpreting the results of this study it should be borne in mind that nitrogen fertilization increased the yields very greatly. Its effect was most pronounced in the first experimental year and declined toward the end of the three-

Table 1. Effects of nitrogen fertilization, soils, plant species, cutting time and age of ley on the Fe, Mn, Na, Zn, Cu, Sr, Mo and Co contents in D.M. of ley grasses. The TUKEY test (STEELE and TORRIE 1960) was applied to test the differences between the averages. a—c : $P < 0.05$. Values followed by the same letter do not differ significantly ($P < 0.05$) from each other.

	Fe	Mn	Na	Zn	Cu	Sr	Mo	Co
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Number of samples	1 599	1 599	1 599	1 599	1 143	339	89	89
NITROGEN FERTILIZATION								
kg/ha/yr								
0	242^{b}	172^{c}	49^{a}	30^{a}	10.0^{a}	36^{a}	1.94^{b}	$.23^{a}$
150	169^{a}	122^{b}	72^{a}	32^{a}	11.1^{a}	35^{a}	1.11^{a}	$.23^{a}$
300	176^{a}	100^{a}	212^{b}	35^{b}	11.1^{ab}	35^{a}	0.87^{a}	$.23^{a}$
450	173^{a}	100^{a}	293^{bc}	38^{bc}	11.4^{ab}	37^{a}	0.74^{a}	$.24^{a}$
600	180^{a}	101^{a}	326^{c}	39^{c}	12.1^{b}	39^{a}	0.66^{a}	$.25^{a}$
SOILS								
Coarse mineral soils	189^{ab}	128^{b}	226^{b}	35^{a}	9.8^{a}	45^{b}	0.99^{a}	$.24^{a}$
Fine mineral soils	192^{b}	100^{a}	89^{a}	35^{a}	11.4^{b}	27^{a}	1.56^{b}	$.22^{a}$
Organogenic soils	166^{a}	177^{c}	519^{c}	34^{a}	12.0^{b}	45^{b}	0.65^{a}	$.26^{b}$
SPECIES								
Meadow fescue	202^{b}	91^{a}	76^{a}	34^{a}	10.0^{a}	41^{b}	1.22^{b}	$.24^{a}$
Cocksfoot	174^{a}	147^{b}	303^{b}	36^{b}	11.8^{b}	32^{a}	0.90^{a}	$.23^{a}$
CUT no.								
I	184^{b}	85^{a}	111^{a}	35^{b}	10.5^{a}	33^{a}	..	..
II	165^{a}	123^{b}	193^{b}	32^{a}	11.1^{a}	39^{ab}	..	..
III—IV [1]	214^{c}	149^{c}	263^{c}	37^{c}	11.0^{a}	37^{b}	..	..
AGE of the ley, years								
1	201^{b}	123^{a}	106^{a}	36^{a}	9.6^{a}	..	1.36^{b}	$.23^{a}$
2	188^{ab}	115^{a}	188^{b}	34^{a}	9.0^{a}	..	1.05^{ab}	$.23^{ab}$
3	174^{a}	119^{a}	284^{c}	35^{a}	13.1^{b}	..	0.79^{a}	$.26^{b}$
Aver., whole material	188	119	189	35	10.9	36	1.06	.24
Standard deviation	±130	±84	±455	±13	±6.3	±13	±0.73	±.04

[1] Cut IV was made at only two sites.

Table 2. F-values for trace element contents.

	Fe	Mn	Na	Zn	Cu	Sr	Mo	Co
Nitrogen fertilization ..	18.5***	48.4***	25.9***	27.3***	4.8***	0.9	14.6***	0.8
Soils	3.0*	74.5***	74.2***	1.5	10.8***	144.3***	15.7***	11.2***
Species	19.4***	202.6***	105.5***	9.0**	25.4***	47.4***	4.3*	1.7
Cutting time	19.8***	87.5***	15.2***	18.5***	1.0	8.0***	..	..
Age of the ley	5.7**	1.1	20.8***	2.1	58.7***	..	4.9**	4.5*

year experimental period. The three-year average dry matter yields at various nitrogen dressing levels were as follows:

Nitrogen fertilization	Dry matter yield
0 kg N/ha/yr	1 980 kg/ha
150 —„—	6 130 —„—
300 —„—	7 910 —„—
450 —„—	8 350 —„—
600 —„—	8 240 —„—

Another factor affecting the results and their interpretation is the decrease in soil pH during the experimental period. On the average (all soils) this decline was 0.10—0.15 pH unit at 150—300 kg N/ha fertilization level. At 450 and 600 kg N/ha levels the decline was 0.29 and 0.41 pH unit, respectively. The effects of nitrogen fertilization on other soil properties also may be reflected in the trace element con-

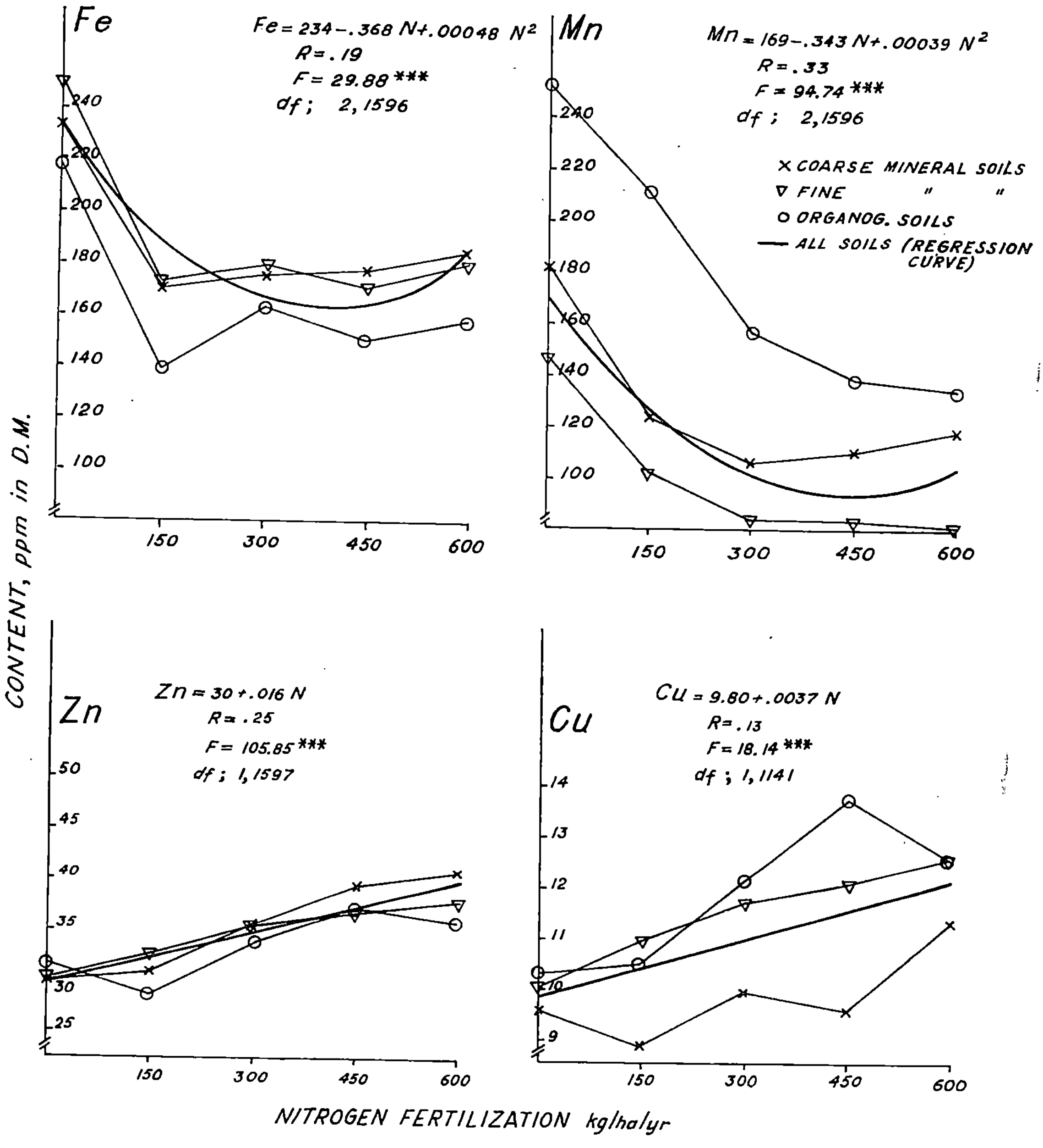

Fig. 1. Regressions of Fe, Mn, Zn and Cu contents in D.M. of ley grasses on nitrogen fertilization (whole experimental material). Broken lines indicate the average nutrient contents at various nitrogen dressing levels for the three soil groups separately.

tents of plants. The results obtained during the same experiments with respect to the changes in soil properties will be published shortly, but have been referred to frequently in this paper when interpreting the results.

Effects of nitrogen fertilization

Nitrogen fertilization decreased the Fe, Mn and Mo contents in D.M. of ley grasses (Tables 1 and 2, Figs. 1 and 2). On the average (incl. all soils, plants, cuts and years) the Fe content decreased from 242 to 173—180 ppm, the Mn content from 172 to 100—101 ppm and Mo content from 1.94 to 0.74—0.66 ppm as the fertilization was increased from 0 to 450—600 kg N/ha. Nitrogen fertilization explained 3.6, 10.6 and 39.8 per cent of the variation in Fe, Mn and Mo, respectively, with statistical significance. The greatest falls were between 0 and 150 kg N/ha, for Fe 73, Mn 50 and Mo 0.83 ppm. No significant differences in the contents of any of these three elements existed between the three highest (300—600 kg N/ha) N treatments. The decreasing effect of nitrogen fertilization on the Fe, Mn and Mo contents of grasses was relatively independent of the grouping of the material, since all coefficients (r-values) given in Table 3 for these elements are negative and most of them statistically significant.

It should be noted, however, that due to increasing yields the total uptake of Fe and Mn by grasses increased with increasing nitrogen fertilization. In spite of this the contents of soluble Fe and Mn in soil increased during the experimental period in plots which received high doses of nitrogen, apparently because of the decreased soil pH (unpublished data). The decrease in Mo content with nitrogen fertilization was so pronounced that in spite of the increasing yields the total uptake of Mo did not increase.

This was apparently due to the decrease in the solubility of soil Mo, caused by the decreased soil pH. In addition, the increase in soluble iron and the decrease in soluble phosphorus in the soil (unpublished data) may have limited the uptake of Mo (Barshad 1951, Jaakkola 1972).

The Na, Zn and Cu contents of ley grasses increased with increasing nitrogen fertilization. On the average the increase in Na was from 49 to 293—326 ppm, in Zn from 30 to 38—39 ppm and in Cu from 10 to 11.4—12.1 ppm as fertilization was increased from 0 to 450—600 kg N/ha (Tables 1 and 2, Figs. 1 and 2). Nitrogen fertilization explained with statistical significance 5.8, 6.2 and 1.6 per cent of the variation in Na, Zn and Cu contents, respectively. All coefficients for correlations between nitrogen fertilization and the Na and Zn contents in grasses are positive and, with few exceptions, highly significant (Table 3). For Cu, only seven out of the 18 coefficients reached the level of significance. Due to the increases in the Na, Zn and Cu contents in grasses and to the increasing yields with increasing N fertilization, the total uptake of these elements by yields became manifold.

The average Sr and Co contents of grasses seem to be relatively independent of nitrogen fertilization (Tables 1 and 2, Fig. 2), although signs of the influence of nitrogen can be seen within some subgroups of the material (Table 3).

Soils

The Fe content of grasses grown on fine mineral soil was the highest (192 ppm) and that on organogenic soils the lowest (166 ppm). The difference was statistically significant (Tables 1 and 2). Only in grasses on fine mineral soils was the Fe content significantly reduced by nitrogen fertilization (Table 3). The soluble Fe contents in soils were not reflected in the Fe contents of plants grown on different soils (unpublished data). The reason for this cannot be explained on the basis of the present results. Among other things, the antagonism between Mn and Fe may have had an effect on this phenomenon.

The highest average Mn and Na contents, 177 and 519 ppm respectively, were found in ley grasses grown on organogenic soils; on coarse mineral soils these figures were 128 and 226 ppm and on fine mineral soil 100 and 89 ppm, respectively. The differences were significant (Tables 1 and 2). The soluble Mn and Na contents in soil were also considerably higher in organogenic than in other soils (unpublished data). Nitrogen fertilization decreased Mn and increased Na contents significantly on all soils. The changes were most pronounced on organogenic soils (Table 3, Figs. 1 and 2).

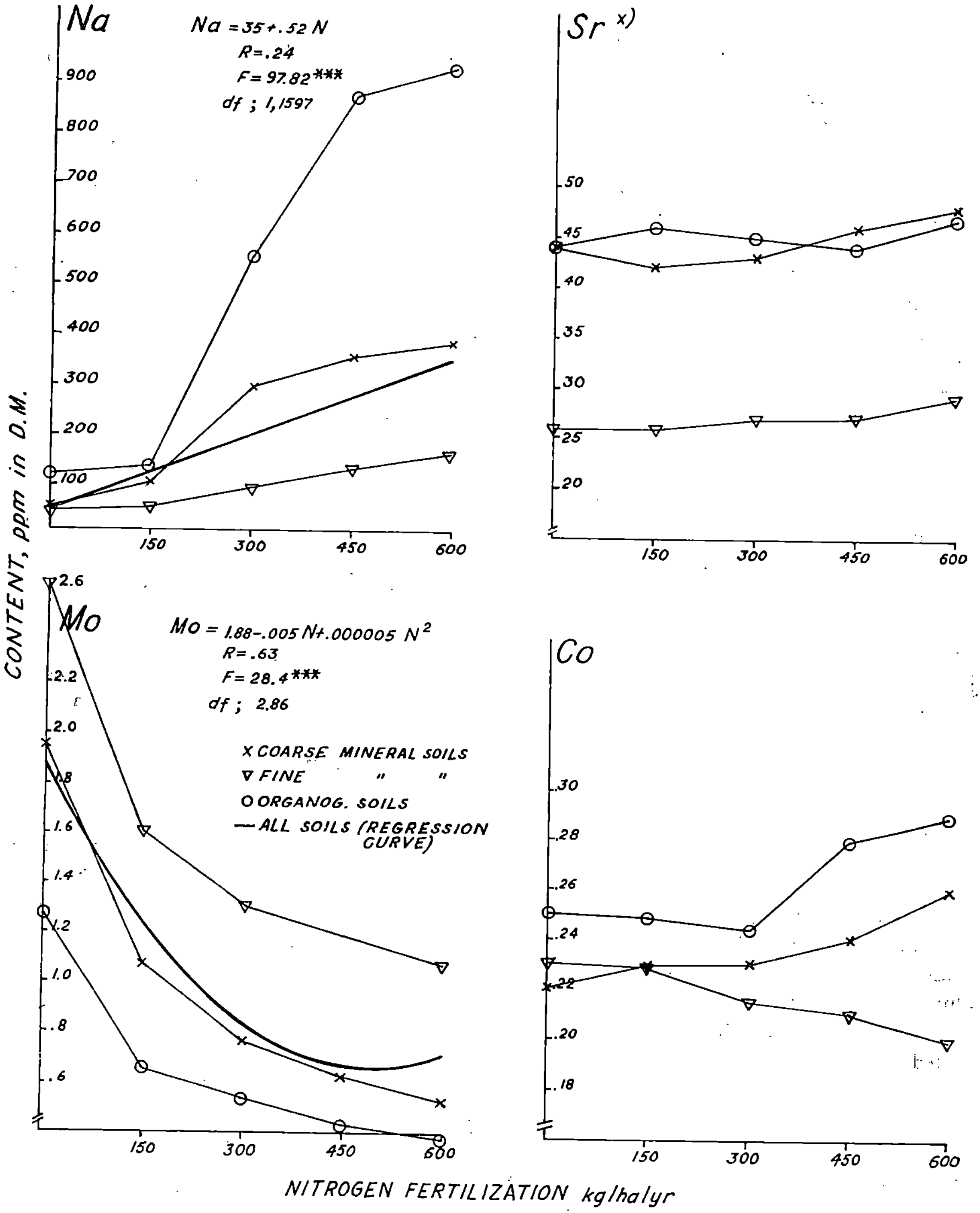

Fig. 2. Regressions of Na and Mo contents in D.M. of ley grasses on nitrogen fertilization (whole experimental material). For Sr and Co regressions were not significant. Broken lines indicate the average nutrient contents at various nitrogen dressing levels for the three soil groups separately.

x) Results of the first year only.

Table 3. Coefficients (r-values) for the eight trace element contents on the nitrogen fertilization, and differences in homogeneity (χ^2) between correlations.

	Fe	Mn	Na	Zn	Cu	Sr	Mo	Co
				Meadow fescue				
SOILS								
Coarse mineral soils	—.09	—.15**	.22***	.34***	.10	.29**	—.80***	.79***
Fine mineral soils	—.19***	—.34***	.24***	.30***	.20***	.30**	—.72**	—.44
Organogenic soils	—.13	—.46***	.40***	.30**	.07	.31	—.80***	.69**
Sign. of diff. χ^2	ns	***	ns	ns	ns	ns	ns	***
CUTS								
I	—.15*	—.02	.31***	.41***	.02	.25	..	..
II	—.07	—.29***	.20**	.42***	.17*	.19	..	..
III	—.21***	—.45***	.24***	.18***	.27***	.13	..	..
Sign. of diff. χ^2	ns	***	ns	**	ns	ns		
AGE, YEARS								
1	—.10	—.37***	.27***	.38***	.32**	.18*	—.62*	.21
2	—.15*	—.27***	.33***	.33***	.24***	..	—.70**	.54*
3	—.17***	—.15*	.26***	.22***	.04	..	—.73**	.28
Sign. of diff. χ^2	ns	*	ns	ns	*		ns	ns
				Cocksfoot				
SOILS								
Coarse mineral soils	—.09	—.35***	.41***	.23***	.12	—.00	—.72**	.01
Fine mineral soils	—.16**	—.35***	.26***	.16**	.11	—.04	—.62*	—.38
Organogenic soils	—.11	—.46***	.49***	.05	.12	—.24	—.80***	—.08
Sign. of diff. χ^2	ns	ns	*	ns	ns	ns	ns	ns
CUTS								
I	—.13*	—.21***	.47***	.26***	.09	.10	..	..
II	—.06	—.43***	.33***	.22***	.14	—.02	..	..
III	—.18**	—.41***	.32***	.10	.10	—.11	..	..
Sign. of diff. χ^2	ns	**	ns	ns	ns	ns		
AGE, YEARS								
1	—.11	—.38***	.31***	.18**	.32**	—.02	—.59*	—.36
2	—.09	—.35***	.36***	.17**	.25***	..	—.62*	—.28
3	—.19**	—.28***	.33***	.18**	.02	..	—.67**	—.07
Sign. of diff. χ^2	ns	ns	ns	ns	**		ns	ns

There was no significant variation in the Zn content attributable to soil type. On coarse mineral soils the increasing effect of nitrogen fertilization on Zn content was, however, somewhat stronger than on other soils (Tables 1 and 3, Fig. 1).

The average Cu content was significantly lower in grasses grown on coarse mineral soils than in those on other soils (Tables 1 and 2). Although the increase in Cu content due to nitrogen fertilization was significant for the whole material, for different soil groups statistical significance was reached only in the case of fine mineral soils (Table 3, Fig. 1).

Being chemically related to Ca, the behaviour and amounts of Sr in grasses grown on different soils resemble those of Ca (Rinne et al. 1974). Grasses grown on fine mineral soils had significantly lower average Sr content (27 ppm) than those grown on other soils (45 ppm) and changes due to nitrogen fertilization were only slight (Tables 1 and 3, Fig. 2).

Grasses grown on fine mineral soils had significantly higher Mo content (1.56 ppm) than those grown on coarse mineral soils (0.99 ppm) or on organogenic soils (0.65 ppm) (Tables 1 and 2). The decreasing effect of nitrogen on Mo content was strong on all soils and there were no significant differences attributable to the soil types (Table 3, Fig. 2).

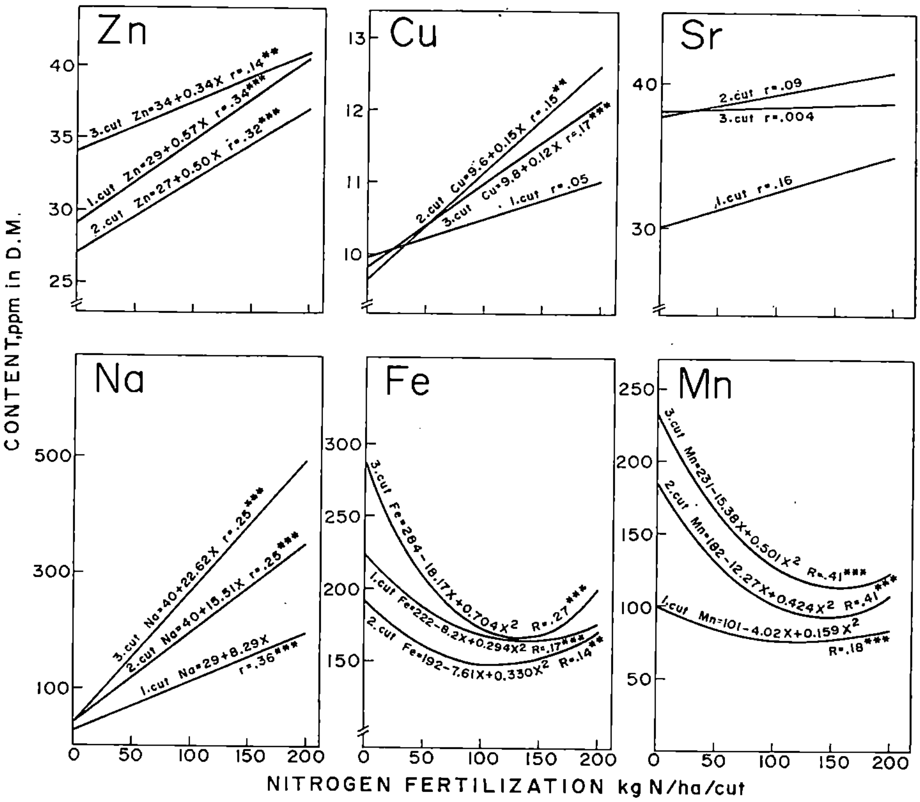

Fig. 3. Regressions of Zn, Cu, Sr, Na, Fe and Mn contents on nitrogen fertilization for the three cuts (all soils, plants and years). $X = N \times 10^{-1}$ kg/ha/cut.

The average Co content was significantly higher in grasses grown on organogenic than on other soils (Table 1). The effect of nitrogen dressing on Co content was obscure, decreasing it in grasses grown on fine mineral soils but increasing it in those grown on other soils (Table 3, Fig. 2). For the whole sample material therefore, nitrogen had no significant effect on Co content.

Plant species

The trace element contents of the two plant species studied, meadow fescue and cocksfoot, differed considerably from each other. Fescue had significantly higher average Fe, Sr and Mo content than cocksfoot, while the Mn, Na, Zn and Cu contents of cocksfoot exceeded those of fescue significantly. The greatest differences were those found in the Mn and Na contents, which in cocksfoot were respectively 1.6 and 4 times as great as those in fescue. There was no difference in the average Co contents of the two plant species (Tables 1 and 2).

The effect of nitrogen fertilization on trace element contents did not differ greatly between the two plants. However, in the case of Mn and Na the correlations between the contents of these elements and nitrogen were somewhat stronger for cocksfoot than for fescue, while nitrogen seems to have more effect on the amounts of other elements found in fescue than on those in cocksfoot (Table 3).

Cutting time

Data on the significance of cutting time on trace elements were obtained only for six elements. In general, the highest contents were found in grasses of the latest cuts (Table 1). The average Mn, Na and Sr contents were lowest in grasses of the first cut while those of Fe and Zn were lowest in second cut grasses. There were no significant differences between the cuts in the average Cu contents.

The greatest differences attributable to cutting time were found in the Na and Mn contents. Average Na content increased from 111 ppm in the first cut to 263 ppm in the autumn cut, or multiplied 2.4 times. Correspondingly, Mn content increased from 85 to 149, despite the strong decrease due to nitrogen dressing in the autumn (Table 1, Fig. 3).

The effect of nitrogen fertilization varied from one cut to another depending on the element. Its influence in decreasing Fe and Mn contents was most pronounced in the autumn (Fig. 3). Nitrogen increased the Na and Cu contents much less in grasses from the first cut than in those from the later cuts while its influence in increasing the Zn content was strongest in the grass cut first (Fig. 3).

Age of the ley

The average Fe content of ley grasses decreased toward the end of the experimental period in spite of the simultaneous increase in soluble Fe in soils.

Age of the ley had no significant effect on the average Mn content of the grasses. Nitrogen fertilization decreased the Mn content regardless of the year, but its effect was more pronounced in the first than in later years (Table 3).

From the first to the third growing season the average Na content in grasses increased significantly, from 106 to 284 ppm (Tables 1 and 2). Regarding the effect of nitrogen, there were no significant differences between the years.

Age of the ley had no significant effect on the Zn content in ley grasses. For Cu the difference between the years was due to exceptionally high Cu contents during the third growing season. In the case of Co also, the significance of age of the ley seems to be relatively small. The average Mo content of grasses decreased from 1.36 ppm in the first year to 0.79 ppm in the third year. This decrease is apparently a consequence of the reduction in the solubility of soil Mo due to lowered pH caused by nitrogen fertilization (unpublished data).

REFERENCES

Barshad, I. 1951. Factors affecting the molybdenum content of pasture plants. I. Nature of soil molybdenum, growth of plants, and soil pH. Soil Sci. 71: 297—313.

Hemingway, R. G. 1962. Copper, molybdenum, manganese and iron contents of herbage as influenced by fertilizer treatments over a three year period. J. Brit. Grassl. Soc. 17: 182—187.

Huokuna, E. & Hiivola, S.-L. 1974. The effect of heavy nitrogen fertilization on sward density and winter survival of grasses. Ann. Agric. Fenn. 13: 88—95.

Jaakkola, A. 1972. Availability to plants of molybdenum in Finnish mineral soils. Acta Agr. Fenn. 126: 1—92.

Raininko, K. 1968. The effects of nitrogen fertilization, irrigation and number of harvestings upon leys established with various seed mixtures. Acta Agr. Fenn. 112: 1—137.

Reith, J. W. S. & Mitchell, R. I. 1964. The effect of soil treatment on trace element uptake by plants. Plant Anal. Fert. Probl. 4: 241—254.

Rinne, S.-L., Sillanpää, M., Huokuna, E. & Hiivola, S.-L. 1974. Effects of heavy nitrogen fertilization on potassium, calcium, magnesium and phosphorus contents in ley grasses. Ann. Agric. Fenn. 13: 96—108.

Snedecor, G. W. & Cochran, W. G. 1971. Statistical methods. 593 p. Ames, Iowa.

Steele, R. G. & Torrie, J. H. 1960. Principles and procedures of statistics. 481 p. New York.

Whitehead, D. C. 1966. Data on the mineral composition of grassland herbage from the Grassland Research Institute and the Welsh Plant Breeding Station, Aberystwyth. Grassl. Res. Inst. Techn. Rep. 4: 1—55.

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SELOSTUS

Runsaan typpilannoituksen vaikutus säilörehunurmien rauta-, mangaani-, natrium-, sinkki-, kupari-, strontium-, molybdeeni- ja kobolttipitoisuuteen

Sirkka-Liisa Rinne, Mikko Sillanpää, Erkki Huokuna ja Sirkka-Liisa Hiivola

Maatalouden tutkimuskeskus

Typpilannoituksen (0—600 kg N/ha/v) vaikutusta säilörehuasteella korjatun nurminadan ja koiranheinän hivenainepitoisuuteen tutkittiin vuosina 1967—70 18 koepaikalla. Typpilannoitus (Oulunsalpietari) nosti tilastollisesti merkitsevästi sadon natrium-, sinkki- ja kuparipitoisuutta, sen sijaan rauta-, mangaani- ja molybdeenipitoisuutta se merkitsevästi laski. Strontium- ja kobolttipitoisuuteen lannoituksella ei ollut yhtenäistä vaikutusta (taul. 1, kuvat 1 ja 2).

Typen välittömän vaikutuksen lisäksi lannoitus vaikutti myös välillisesti satojen hivenainepitoisuuksiin alentamalla maan pH:ta. Koska hivenaineiden liukoisuus olennaisesti riippuu maan happamuudesta, pH:n aleneminen typpitason noustessa lisäsi muiden kasveille käyttökelpoisten hivenaineiden määriä paitsi Mo:n, jonka liukoisuus vähenee pH:n laskiessa. Eri tekijöiden vaikutuksia on vaikea rajata, mutta ilmeisesti tässä kokeessa pH:n aleneminen tehosti typpilannoituksen Zn- ja Cu-pitoisuuksia nostavaa ja heikensi sen Fe- ja Mn-pitoisuuksia laskevaa vaikutusta, mikä selittää myös Fe- ja Mn-pitoisuuksien käyräviivaiset muutokset typpitason kohotessa. Ylimmillä typpitasoillahan pH:n aleneminen ja hivenaineiden liukoisuuden lisääntyminen oli voimakkainta.

Molempien tekijöiden, typen ja pH:n, alenemisen samansuuntainen, negatiivinen vaikutus johti molybdeenin erittäin voimakkaaseen vähentymiseen sadossa.

Vaikka typpilannoituksen vaikutus kuhunkin hivenaineeseen olikin melko yhtenäinen kaikissa tutkituissa ryhmissä, se selitti kuitenkin vain pienen osan pitoisuuksien vaihteluista, sillä maalajien, kasvilajien, niittokertojen ja vuosien välillä oli erittäin merkitseviä eroja satojen hivenainepitoisuuksissa.

Maalajin vaikutus ruohon hivenainepitoisuuteen oli merkitsevä. Hienoilla kivennäismailla sadot sisälsivät vähemmän Mn, Na, Sr ja Co ja enemmän Fe sekä Mo kuin muilla maalajeilla. Eloperäisillä mailla sadon Mn-, Na- ja Co-pitoisuudet olivat tilastollisesti merkitsevästi korkeimmat, ja karkeille kivennäismaille oli tyypillistä merkitsevästi alhaisempi satojen Cu-pitoisuus kuin muille maalajeille (taul. 1). Typpilannoitus vaikutti Co-pitoisuuteen eri tavoin eri maalajeilla: eloperäisillä ja karkeilla kivennäismailla se nosti sadon Co-pitoisuutta, hienoilla kivennäismailla laski.

Myös kasvilajien välillä oli erittäin merkitseviä eroja (taul. 1 ja 2). Nurminadan keskimääräiset Fe-, Sr- ja Mo-pitoisuudet olivat korkeammat ja Mn-, Na-, Zn- ja Cu-pitoisuudet alhaisemmat kuin koiranheinän. Kasvukausi vaikutti siten, että hivenainepitoisuudet olivat yleensä korkeimmillaan syyssadoissa. Na-, Cu- ja Co-pitoisuudet nousivat myös nurmen iän kasvaessa, Fe- ja Mo-pitoisuudet sen sijaan laskivat (taul. 1).

ANNALES AGRICULTURAE FENNIAE, VOL. 13: 119—124 (1974)

Seria AGRICULTURA N. 47 — Sarja PELTOVILJELY n:o 47

GROWTH AND HERBAGE QUALITY OF MEADOW FESCUE (FESTUCA PRATENSIS HUDS.) UNDER DIFFERENT WEATHER CONDITIONS

TIMO MELA

MELA, T. 1974. **Growth and herbage quality of meadow fescue (Festuca pratensis Huds.) under different weather conditions.** Ann. Agric. Fenn. 13: 119—124.

Meadow fescue grew with uniform vigour throughout the warm and rainy growing season of 1972, and gave 51, 71, 58 and 86 % larger dry matter yields with 2, 3, 4 and 5 cuttings, respectively, than in the dry growing season of 1971. In 1972 the total crude protein yields were equal in the different cutting treatments; in 1971 they decreased with an increase in the number of cuttings. The average crude protein content of the herbage was 0.5—0.9 %-units lower and the crude fibre content was 3.7—2.1 %-units higher with 2—5 cuttings, respectively, in 1972 than in 1971. The results point to the conclusion that the differences in quality were induced by the more rapid development and aging of the herbage in 1972. The crude protein and crude fibre contents showed correlations to the dry matter yields (growth rate).

If the energy and protein supply of cattle is largely based on herbage, it is essential that this should be of high and uniform quality. The main means of controlling, improving and standardizing the quality of herbage yields is by making a careful choice of plant species, varieties, time of cutting and fertilization on the basis of earlier experience.

In grassland farming, the weather conditions are often responsible when the quality of cattle forage produced by methods earlier proved satisfactory falls short of expectations. Evidently, more information about the effect of the weather might increase the farmer's chances of obtaining valuable herbage yields, but relatively little attention has so far been paid to this subject. Wide seasonal variation usually limits the opportunities for studying the significance of the weather for agronomy, but the occurrence of sharply differing precipitation and temperature conditions in the years 1971 and 1972 provided an unusual and welcome chance to make observations.

Materials and methods

In 1971 and 1972 two field experiments were conducted at the Institute of Plant Husbandry, Agricultural Research Centre, Tikkurila (60 °N), to compare the effects of four cutting treatments, comprising 2, 3, 4 and 5 cuttings, on the growth and the crude protein and crude fibre contents of meadow fescue. The intervals between cuttings were the same in the different treatments in the two years, so that differences in quality due to the age of the grass sward were eliminated. The developmental stages of the grass at the first cutting were: a) leaf stage (5 cuttings), b) sheath stage (4 cuttings), c) pre-emergence stage (3 cuttings) and d) full-emergence stage

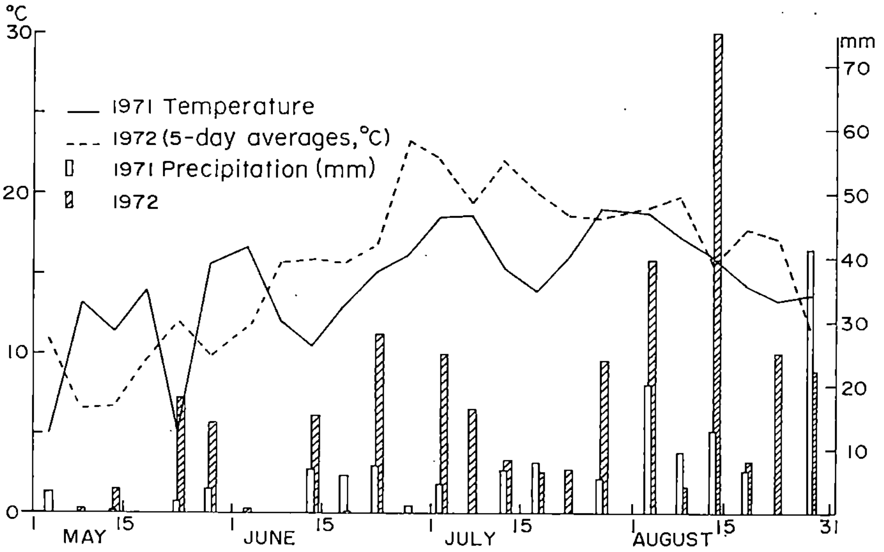

Fig. 1. Temperature and precipitation in May—August, 1971—72.

(2 cuttings). The date of the last cutting in all the treatments, August 30 in both experiments, was selected in the spring, in order that the cutting intervals might be calculated in advance.

The experiments were made on first year grass swards. The soil type was loamy clay in both years. PK fertilizer was applied each year in the spring, at rates of 85 kg/ha P_2O_5 and 75 kg/ha K_2O. Nitrogen fertilizer was applied at the rate of 300 kg/ha N during the period of growth, as follows:

	2 cuttings kg/ha	3 cuttings kg/ha	4 cuttings kg/ha	5 cuttings kg/ha
Spring	200	150	100	100
After 1st cutting	100	75	70	50
„ 2nd „	—	75	70	50
„ 3rd „	—	—	60	50
„ 4th „	—	—	—	50

The fertilizer used (26 % N) contained equal quantities of ammonium and nitrate nitrogen.

The nitrogen content of the herbage was determined by the Kjehldahl method. The crude protein content was 6.25 × nitrogen content.

Weather conditions

In 1971, temperatures were higher than normal in May, but about normal in June, July and August (Fig. 1). The beginning and middle of the summer were exceptionally dry, but precipitation was normal in August. The evaporation values were high as a result of the dryness of the summer.

In 1972, the average temperature of May corresponded to the long-term average, but June, July and August were clearly warmer. As precipitation was normal in May, and June and much higher in July and August, and fell in showers of suitable magnitude throughout the growing season, conditions in 1972 were particularly favourable for the growth of grass. In spite of the high temperatures, evaporation was lower than normal, except in July.

Growth and quality of herbage

During the warm spring of 1971 the grass grew rapidly and gave a remarkable forage yield as early as on May 21 (Fig. 2). However, since the springtime water reserves became exhausted, and precipitation was insufficient, the rate of growth decreased evenly throughout the growing season.

In the spring of 1972 growth started more slowly than in the preceding year, but was accelerated by the warm weather and rains

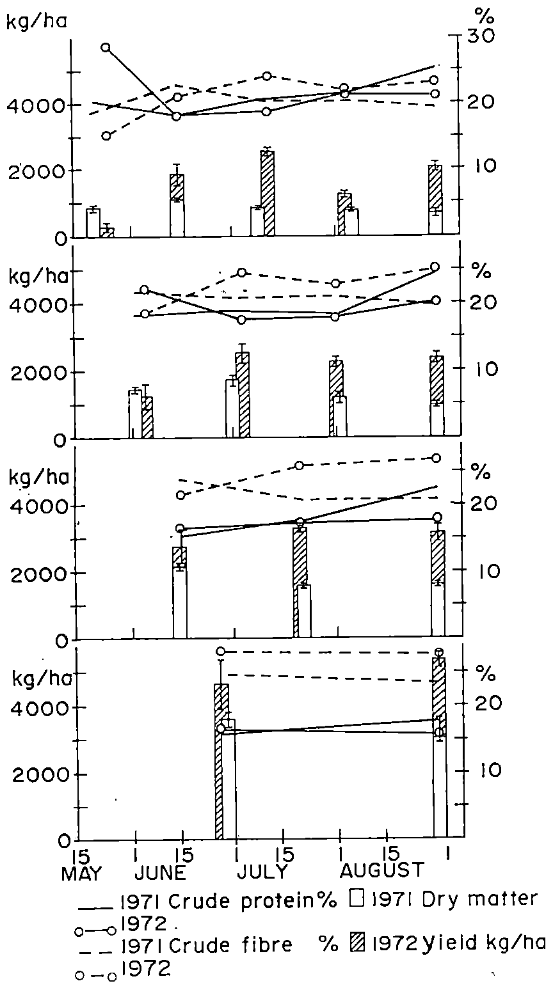

Fig. 2. Dry matter yields and crude protein and crude fibre content of herbage in the different cutting treatments. Vertical line segments indicate the 95 % confidence limits of the dry matter yields.

at the end of May, so that the forage yields were already larger than those in 1971 at the pre-emergence stage on June 15 and the full-emergence stage on June 29. The vigorous growth continued throughout the summer. Only the growth rate of the most frequently cut grass was lowered after the third cutting on July 12, presumably on account of the short relatively dry period occurring at the beginning of re-growth.

The results of the year 1972 show that when precipitation and temperature are sufficiently high, meadow fescue can grow vigorously throughout the summer. As a rule growth is strongest at the beginning of the summer and slows down (Laine 1953, Huokuna 1964) as the days shorten and the temperature decreases towards the autumn.

The total dry matter yields were 51, 71, 58 and 86 % larger with 2, 3, 4 and 5 cuttings, respectively, in 1972 than in 1971 (Table 1).

In 1972 the crude protein yields were the same with the different cutting treatments; in 1971 they decreased as the number of cuttings increased.

The crude protein contents of the total dry matter yields were 0.5—0.9 %-units higher with 2—5 cuttings, respectively, in 1971 than in 1972. Still more notable were the differences between the crude fibre contents of the dry matter yields. They were 3.7—2.1 %-units lower with 2—5 cuttings, respectively, in 1971 than in 1972. The only exception was the yield of the first cutting. Before the pre-emergence stage its quality was better in 1972 than in 1971.

Johnson and Nichols (1969) found that the crude protein content of 11 grasses, meadow fescue included, was higher in a dry year than in a moist year. The differences between the years in the crude protein contents of meadow fescue were 1.3 %-units without nitrogen fertilization and 2.0 %-units with 112 kg/ha nitrogen fertilization. They were thus larger than in the present experiments. The air temperatures of the growing seasons compared by Johnson and Nichols were about equal.

According to Gates (1968), the percentage of crude protein in the dry weight of plants stressed by drought may increase when growth or assimilation is suppressed more than nitrogen uptake. Nitrogen uptake can be suppressed during dry weather when the water available to plants from the surface soil has been exhausted and the fertilizer applied does not reach the root level (Garwood and Williams 1967). Thus the effects of the weather on the crude protein content of herbage are very complex and in many cases extremely difficult to estimate.

Very little information has been obtained about the effect of weather on the crude fibre

Table 1. Total yields and quality of herbage. The crude protein and crude fibre contents are the weighted means of the different cuttings.

		1971				1972			
		2 cuttings	3 cuttings	4 cuttings	5 cuttings	2 cuttings	3 cuttings	4 cuttings	5 cuttings
Dry matter yield,	kg/ha	6 600	5 390	5 300	4 260	9 980	9 200	8 360	7 940
	rel.	100	82	80	65	100	92	84	80
Crude protein yield,	kg/ha	1 090	980	1 040	890	1 600	1 580	1 590	1 580
	rel.	100	89	95	81	100	99	99	99
Crude protein content,	%	16.6	18.1	19.5	20.7	16.0	17.2	19.0	19.8
Crude fibre content,	%	24.1	21.9	21.1	20.6	27.8	24.8	23.2	22.7

content of herbage. However, MINSON and McLEOD (1970) reported that the higher the temperature during the growth of grasses, the lower was their digestibility. Probably a change in the crude fibre content was involved, although this component was not determined, since a high correlation has been found between the digestibility and the crude fibre content of herbage (KIVIMÄE 1959).

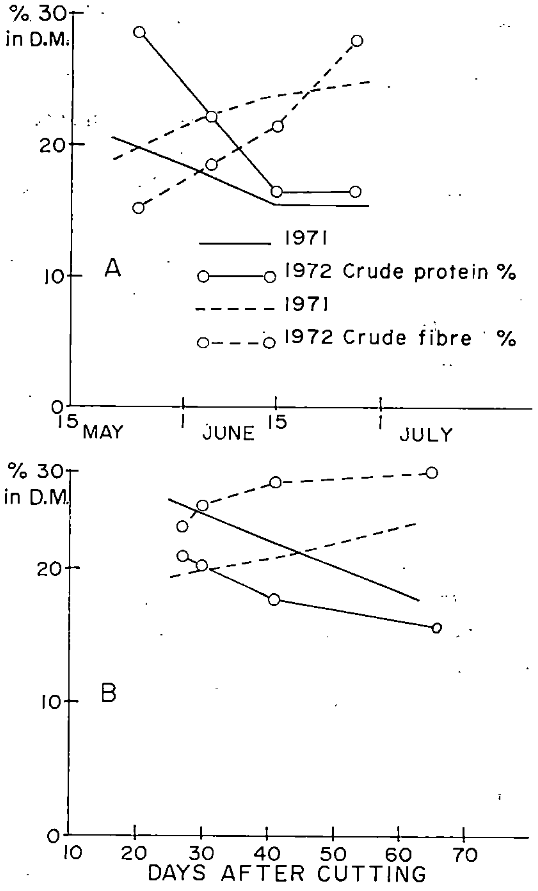

Fig. 3. Change of herbage quality at the beginning of the growing season (A) and before the last cutting (B). Fig. 3 B shows the crude protein and crude fibre content of herbage on August 30 after different growing periods.

Fig. 3 shows that the changes in the crude protein and crude fibre contents of meadow fescue were accelerated by the favourable weather conditions in 1972. It may therefore be concluded that the principal reason for differences in the quality of the herbage between the two years was the rapid aging of the grass in 1972. An increase of cell wall material in developing leaf tissue at the expense of proteins and nucleic acids was demonstrated by WILLIAMS and RIJVEN (1965), and this is probably related to the growth rate.

The changes in the composition of the yield of the first cutting are also connected with the high rate of growth of the culms, which are of poorer quality than the leaves (MOWAT et al. 1965). On the other hand, in regrowth after the first cutting meadow fescue develops culms only if the cutting is made very early or high.

The relations between the growth rate (dry matter yield) and the crude protein and crude fibre contents are shown in Figs. 2 and 4. The negative correlation between the crude protein content and the dry matter yield increased with the number of cuttings and the correlation coefficient was statistically significant ($P \leqq 0.05$) in the 5-cutting treatment. GOSS (1972) also found a negative relationship between the growth rate and the crude protein content of turf grasses. In the present investigation the crude fibre content of the grass was positively correlated ($P \leqq 0.01$) with the dry matter yields in all the cutting treatments.

A conclusion that may be drawn for grassland farming is that in favourable temperature and moisture conditions, when grass is growing vigorously, meadow fescue sward has to be cut more frequently to maintain high quality than under dry conditions. The luxuriance of growth should be taken into account, as well as the duration of the growing period, when the cutting time is decided. The decrease in the dry matter yield and at least a part of the increased expense of more frequent cuttings will be compensated by the good quality and high value of the forage.

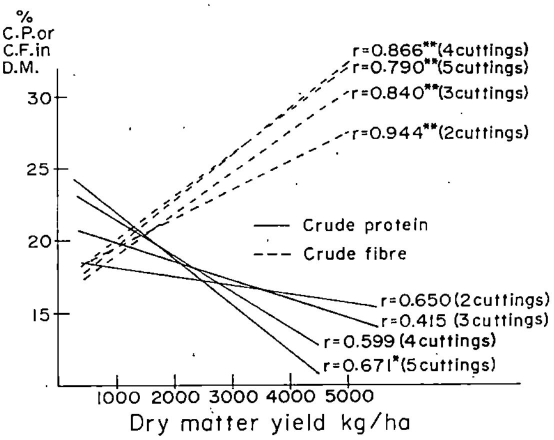

Fig. 4. Relation of crude protein and crude fibre content to dry matter yield (growth rate) of herbage.

REFERENCES

Garwood, E. A. & Williams, T. E. 1967. Growth, water use and nutrient uptake from the subsoil by grass swards. J. Agric. Sci. 69: 125—130.

Gates, C. T. 1968. Water deficits and growth of herbaceous plants. Water deficits and plant growth II: 135—190. Ed. T. T. Kozlowski. New York.

Goss, R. L. 1972. Nutrient uptake and assimilation for quality turf versus maximum vegetation growth. The biology and utilization of grasses. p. 278—291. Ed. V. B. Youngner and C. M. McKell. New York.

Huokuna, E. 1964. The effect of frequency and height of cutting on cocksfoot swards. Ann. Agric. Fenn. 3, Suppl. 4: 1—83.

Johnson, J. R. & Nichols, J. T. 1969. Crude protein content of eleven grasses as affected by yearly variation, legume association, and fertilization. Agron. J.: 65—68.

Kivimäe, A. 1959. Chemical composition and digestibility of some grassland crops. Acta Agric. Scand. 1959, Suppl. 5: 1—142.

Laine, T. 1953. Menetelmä laidunnurmen keskimääräistä kasvua kuvaavan käyrän laatimiseksi. J. Sci. Agric. Soc. Finl. 25: 185—192.

Minson, D. J. & McLeod, M. N. 1970. The digestibility of temperate and tropical grasses. Proc. 10. Intern. Grassl. Congr. p. 719—723.

Mowat, D. N., Fulkerson, R. S., Tossell, W. E. & Winch, J. E. 1965. The in vitro digestibility and protein content of leaf and stem portions of forages. Can. J. Pl. Sci. 45: 321—331.

Williams, R. F. & Rijven, A. H. 1965. The physiology of growth in the wheat plant. II. The dynamics of leaf growth. Austr. J. Biol. Sci. 18: 721—743.

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SELOSTUS

Nurminatanurmen kasvu ja ruohon laatu erilaisissa kasvuoloissa

Timo Mela

Maatalouden tutkimuskeskus

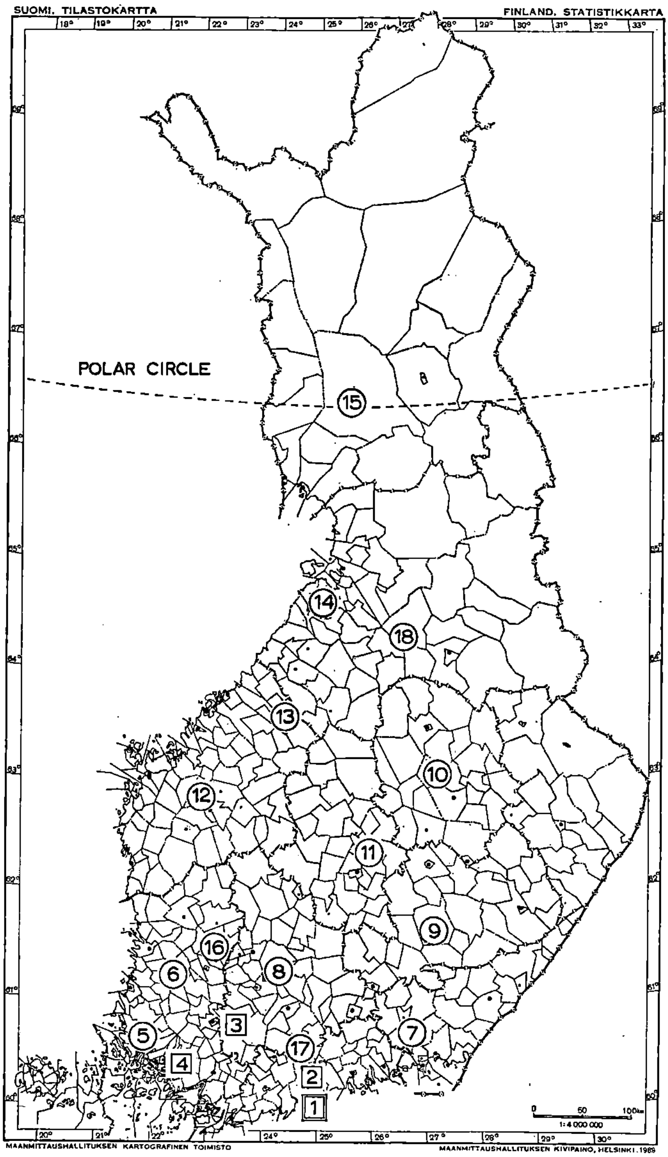
Nurmisadon laadun vuotuinen vaihtelu aiheuttaa usein yllätyksiä, kun koetuilla menetelmillä viljellyn ja korjatun nurmirehun laatu ei vastaakaan odotuksia. Yllättävän heikkolaatuista rehua saatiin nurmista mm.

v. 1972. Kun kasvukausi 1972 oli lämpö- ja sadeoloiltaan nurmien kasvulle erityisen suotuisa ja edellinen kasvukausi 1971 taas poikkeuksellisen vähäsateinen, tarjoaa näiltä kahdelta vuodelta peräisin oleva koeaineisto erinomaisen tilaisuuden tehdä päätelmiä kasvuolojen vaikutuksista nurmen kasvuun ja nurmisadon laatuun.

Koeaineisto käsittää Kasvinviljelylaitoksella Tikkurilassa suoritetut kokeet, joissa verrattiin neljän niittokäsittelyn — 2, 3, 4 ja 5 niittoa — vaikutuksia nurminataan. Niittokäsittelyittäin saman pituiset niittovälit mahdollistavat vuosien välisen vertailun.

Nurminata kasvoi v. 1972 voimakkaasti kasvukauden loppuun saakka. Kokonaiskuiva-ainesadot muodostuivat 2, 3, 4 ja 5 niittokerralla vastaavasti 51, 71, 58 ja 86 % suuremmiksi kuin v. 1971. Vuonna 1972 eri niittokäsittelyt antoivat yhtä suuret raakavalkuaissadot, kun taas v. 1971 ne pienenivät niittokertojen lisääntyessä. Ruohon raakavalkuaispitoisuus oli 0.5—0.9 %-yksikköä alempi ja raakakuitupitoisuus 3.7—2.1 %-yksikköä korkeampi 2—5 niittokerralla v. 1972 kuin v. 1971. Laatuerojen päätellään johtuneen ruohon nopeammasta kehityksestä ja vanhenemisesta v. 1972 kuin v. 1971. Tämä tulos on päinvastainen kuin yleinen käsitys, jonka mukaan nimenomaan kuivuus saa aikaan ruohon laadun nopean heikkenemisen. Raakavalkuais- ja raakakuitupitoisuudet korreloivat niittokäsittelyittäin kuiva-ainesatoihin (kasvunopeuteen).

Tulosten perusteella nurmisato olisi laatua silmälläpitäen korjattava useammin edullisena kasvukautena kuin silloin, kun kasvu on kuivuuden takia estynyt.



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