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ANNALES AGRICULTURAE FENNIAE, VOL. 17: 153—157 (1978)
Seria AGROGEOLOGIA ET -CHIMICA N. 87 — Sarja MAA JA LANNOITUS n:o 87

AVAILABILITY OF SOIL RESERVES OF COPPER, IRON AND MANGANESE

JOUKO SIPPOLA

SIPPOLA, J. 1978: **Availability of soil reserves of copper, iron and manganese.** Ann. Agric. Fenn. 17: 153—157. (Agric. Res. Centre, Inst. Soil Sci., SF-01300 Vantaa 30, Finland).

The removal of copper, iron and manganese from soils by plants was studied in a pot experiment. Soils differing in texture were diluted with quartz sand in a ratio of 1:9. Four successive crops were grown.

The low manganese content was the most limiting growth factor for crops grown in plain quartz sand. The copper, iron and manganese contents of the plants showed a decreasing trend with successive croppings, indicating diminution in available soil reserves.

The total uptake by four crops was 1,2—2,2 % of soil total content for manganese, 0,6—1,3 % for copper and 0,01—0,05 % for iron depending on soil type. In spite of considerable differences in the total micronutrient contents of various soils, the differences between their micronutrient releasing capacities were small.

Index words: Copper, iron and manganese reserves

INTRODUCTION

In Finland the total amounts of micronutrients in mineral soils depend on soil texture. For example the copper and zinc contents of heavy clay soils are several times higher than those of sand soils (VUORINEN 1958). The dependence of micronutrient content on texture is related to the differences in mineralogy of particles of various sizes (SIPPOLA 1975). The extractable micronutrient contents are also closely related to soil texture (SILLANPÄÄ and LAKANEN 1966).

During the weathering process of soil parent material, the elements crystallized in mineral structures are released either in a form available to plants, or bound as unavailable, new compounds. Although the total micronutrient contents of clay soils are high, it does not necessarily mean that clay soils release trace elements to plants in high quantities.

The purpose of the present study was to find out if the same differences found in soil total and extractable micronutrient contents exist also in their capacity to release trace elements to plants. This was attempted by repeated croppings on soils diluted with quartz sand.

MATERIALS AND METHODS

Four subsoil samples, representing different textural types, were selected for the study (Table 1). These soils (100 g) were mixed with acid-washed quartz sand (900 g) and placed into one liter plastic pots. Pure quartz sand was included in the study as a control. Barley was sown into the pots and, after emerging, thinned to 16 plants per pot. The experiment involved a randomised block design with four replications. Major nutrients were added twice with irrigation water, first after thinning and then after two weeks' growth. The total amounts of nutrients put into each pot were as follows: N 200 mg, P 40 mg, K 88 mg, S 20 mg and Mg 34 mg. Nutrient solutions used were prepared from analytical grade reagents.

Table 1. Information on the soil samples.

Textural class	pH	Organic carbon %	Particle size compositon %		
			< 2 μm	2—20 μm	> 20 μm
Heavy clay ..	6,6	0,7	88	6	6
Silty clay ...	5,9	0,6	50	34	16
Silt	5,8	0,9	27	68	5
Finer finesand	5,6	0,6	12	35	53

Four crops were grown successively for a period of 37—44 days each. Between croppings, the pots were leached with deionized water to remove accumulated salts. The crops were harvested at the heading stage. The plants were pulled out of the soil and their roots washed clean. Then they were dried, weighed and ground. For analysis, 5 g of plant material was dry ashed at 450 °C. The ash was treated with HF to remove silica, and with $HClO_4$ to remove the residual carbon. The salts were taken up into 10 ml of 6 N HCl and finally diluted to 100 ml. Cu, Mn and Fe were determined with an atomic absorption spectrometer. Soils were tested for total micronutrient content according to PRATT (1965).

RESULTS AND DISCUSSION

Yields and contents of micronutrients. The mean dry matter yield of the four crops grown in the four soils ranged from 2,45 to 3,05 g/pot. The mean yield of the barley grown in the plain quartz sand was 2,08 g indicating that growth was possible on elements provided by seeds and impurities in the irrigation water and fertilizers. The concentration of manganese in plants grown in quartz sand ranged from 7—19 mg/kg (Table 2). These concentrations are below the deficiency limit of 20 mg/kg for manganese (FINCK 1968).

Copper and iron did not appear to limit growth in the plain quartz sand, because the concentrations of these elements in the plants were well above their deficiency level of 3 mg/kg and 50 mg/kg, respectively.

In plants grown in pots containing soil, the concentration of copper was not significantly higher than in plants grown in quartz sand. In the case of iron, this difference was clear and

Table 2. Concentration of copper, iron and manganese in barley grown in soils diluted with quartz sand (ratio 1 to 9) and in plain quartz sand.

Soil	Crop	Concentration ppm		
		Cu	Fe	Mn
Heavy clay	I	14	143	140
	II	11	272	90
	III	11	120	110
	IV	9	150	80
Silty clay	I	17	128	160
	II	10	344	100
	III	8	175	100
	IV	7	127	120
Silt	I	16	243	250
	II	12	668	190
	III	7	247	190
	IV	7	174	140
Finer finesand	I	18	261	90
	II	12	542	60
	III	10	280	100
	IV	8	149	80
Quartz sand	I	15	90	19
	II	11	157	7
	III	8	123	9
	IV	9	84	16

Table 3. Total content of copper, iron and manganese in soils; the total uptake by four crops and the percentage uptake of soil totals.

		Cu	Fe	Mn
Heavy clay	Soil total, mg/kg	95	81 200	745
	Uptake by 4 crops, mg/kg	0,6	10,4	12,9
	Uptake of soil total, %	0,6	0,01	1,7
Silty clay	Soil total, mg/kg	41	46 350	690
	Uptake by 4 crops, mg/kg	0,5	13,0	15,1
	Uptake of soil total, %	1,1	0,03	2,2
Silt	Soil total, mg/kg	27	42 500	1 025
	Uptake by 4 crops, mg/kg	0,3	20,3	21,7
	Uptake of soil total, %	1,3	0,05	2,1
Finer finesand	Soil total, mg/kg	50	50 750	625
	Uptake by 4 crops, mg/kg	0,4	17,7	7,2
	Uptake of soil total, %	0,8	0,04	1,2

the concentrations of manganese in plants grown in pots containing soil were, in many harvests, as high as the concentration of iron. This shows that even the plants of the fourth harvest were still well provided with the trace elements under investigation.

Uptake of micronutrients from soils of different texture. To evaluate the amount of micronutrients taken up from soils, the uptake from quartz sand pots was subtracted from the uptake from pots containing soil.

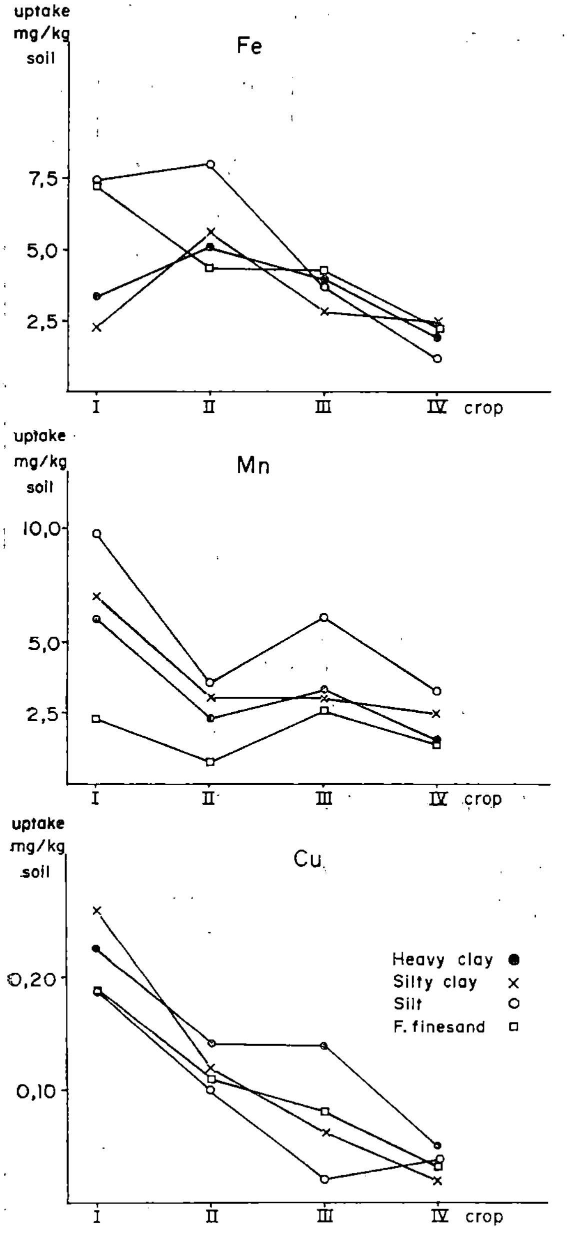
Of the total plant uptake in the control (quartz sand) pots, 20—25 per cent of copper and iron and about 50 per cent of manganese had originated from the seeds (if it is assumed that all of the micronutrients in the seeds were transferred to the plants).

The total uptake of *copper* from the heavy clay soil, 0,6 mg/kg, was higher than that from the other soil types under investigation (Table 3). The copper uptake was also relatively high from the finer finesand soil which had a high total copper content (50 mg/kg, which is more than twice the normal for these soils). The copper of the silt soil was mobilized to a higher degree than that of the other soils. The decrease in copper uptake by successive croppings was most pronounced in the case of the silty clay and silt soils (Fig. 1). From heavy clay, the uptake of copper by the fourth crop was 22 % of that by the first crop. From silt soil, the uptake was only 8 % of that of the first crop, indicating a pronounced decrease in available reserves of copper.

The uptake of *iron* by the first crop was much higher from the coarse textured soils than from the two clay soils (Fig. 1). The differences in uptake between the soils diminished toward the later crops. The decrease in available iron reserves in the silt soil was more pronounced than that of the other soils. A very small portion of the soils' total iron was removed by the plants (Table 3).

The highest *manganese* uptake occurred from the silt soil having the highest total manganese content (Table 3). The uptake from the other soils also seemed to follow the order of their total manganese content. The ratio of uptake to total manganese was higher than that of copper or iron, indicating a relatively short supply of this element in soils.

Micronutrient reserves. Taking into account the dilution of the soils with quartz sand, the total uptake of micronutrients by the four crops corresponded to 30—40 crops under field conditions. Because the contents of micronutrients in all crops grown in pots containing soil were well above the deficiency limits, the shortage of



micronutrients appears to develop relatively slowly. Also the uptake of micronutrients by plants cultivated in the field is likely to differ from that of a pot experiment. For example, the period between croppings was much shorter, giving less time to release fixed elements. The drying and diluting of soil for pot experiments may also affect the release of these elements. There were no considerable differences between the soils in their micronutrient releasing capacity. For example the twice as high total copper and iron contents of the heavy clay did not markedly affect their release as compared to other soils.

Fig. 1. Copper, iron, and manganese uptake by four successive crops of barley from four soils.

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SELOSTUS

Maan kuparin, raudan ja mangaanin reservien käyttökelpoisuus

Jouko Sippola

Maatalouden tutkimuskeskus

Maan kykyä luovuttaa reserveistään kasveille kuparia, mangaania ja rautaa tutkittiin astiakokeessa. Maalajeina olivat aitosavi, hiesusavi, hiesu ja hieno hieta. Maanäytteet (100 g) laimennettiin kvartsihiekalla (900 g) ja täytettiin litran koeastioihin. Koekasvina oli ohra, joka korjattiin tähkälletulovaiheessa. Kaikkiaan kasvatettiin neljä satoa.

Mangaanin puute rajoitti kasvua puhtaassa kvartsihiekassa, mikä oli vertailuna mukana. Tutkittujen hivenaineiden puutetta ei esiintynyt kasveissa, jotka kasvoivat koemaita sisältäneissä astioissa. Kasvien hivenainepitoisuudet olivat kuitenkin neljännessä sadossa selvästi alempia kuin ensimmäisessä tai toisessa sadossa.

Kasvien hivenravinteiden saantia maan reserveistä pyrittiin selvittämään vähentämällä satojen koemaita sisältäneistä astioista ottamista ravinnemääristä puhtaassa kvartsihiekassa kasvaneiden satojen ravinnemäärät, jotka sisälsivät sekä siemenissä että lannoiteliuoksissa koeastioihin tulleet hivenaineet. Neljä satoa otti maasta mangaania määrän, joka maalajista riippuen oli 1,2—2,2 % maan kokonaismangaanin määrästä. Vastaavasti kasvit ottivat kuparia 0,6—1,3 % ja rautaa 0,01—0,05 % maan kokonaismäärästä. Vaikka maalajien välillä oli eroja hivenaineiden kokonaismäärissä, ei kasvien hivenaineiden saannissa ollut maalajien välillä suurta eroa.

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Seria AGROGEOLOGIA ET -CHIMICA N. 88 — Sarja MAA JA LANNOITUS n:o 88

MACRONUTRIENT CONTENTS OF WHEAT DURING THE GROWING SEASON

JOUKO SIPPOLA, TOIVO YLÄRANTA and HÅKAN JANSSON

SIPPOLA, J., YLÄRANTA, T. & JANSSON, H. 1978. **Macronutrient contents of wheat during the growing season.** Ann. Agric. Fenn. 17: 158—162. (Agric. Res. Centre, Inst. Soil Sci., 01300 Vantaa 30, Finland).

The contents of Ca, K, P, and Mg in spring and winter wheats grown on four experimental fields were analyzed twice a week during the growing season.

The nutrient contents decreased considerably from the spring towards the harvesting time. The decrease in Ca content was from 0,4—0,6 to about 0,1 per cent. The K content decreased from 3—5 to 0,5—0,8 per cent, and P content from 0,3—0,5 to about 0,2 per cent. With Mg, the decrease was less marked; from about 0,15 to 0,1 per cent.

No clear differences existed between spring and winter wheat. The differences in macronutrient contents of the soils were reflected in the respective contents in the wheat. These differences were marked in early stages of plant growth and diminished towards the end of the growing season. Therefore, samples for plant analyses should be taken at tillering, preferably at the mid-tillering stage of plant growth.

Index words: wheat, stage of growth, contents of calcium, potassium, phosphorus and magnesium.

INTRODUCTION

Both plant analyses and soil tests have been used to diagnose the nutrient status of soils. An advantage of plant analyses compared with soil tests is that uniform methodology can be used over a wide range of varying soil and climatic conditions. The disadvantages include, for example, the wide variation in nutrient concentrations in different plant species, plant parts and at the different stages of growth, which make it difficult to interpret the results.

According to several studies (e.g. KAILA and ELONEN 1970, RÖBER and MUNK 1975) the highest mineral contents of plants are found at early stages of plant growth, followed by a decrease with further development of the plants. Therefore, the timing of sampling may cause practical difficulties, because, in order to obtain comparable results, samples should be taken at the same stage of growth.

In this study the changes in the contents of macronutrients (Ca, K, P, and Mg) in spring and winter wheat during the growing season are recorded.

MATERIALS AND METHODS

Spring and winter wheat samples were collected from four experimental fields located at Tikkurila in southern Finland and at Mouhijärvi in central Finland. The fertilization of the experimental fields varied slightly. On the average it consisted of 100 kg N, 35 kg P and 47 kg K, 25 kg Ca and 3 kg Mg per hectare. At Tikkurila the spring wheat (variety Ruso) was grown on a sandy clay soil and the winter wheat (Nisu) on a sand soil. At Mouhijärvi the respective soils and varieties were: clayey silt (Svenno) and silty clay (Linna). The macronutrient contents of the experimental soils were determined by using acid ammonium acetate (0,5 N ammonium acetate, 0,5 N acetic acid—pH 4,65) as extractant (Vuorinen and Mäkitie 1955). Analytical data of the soils are given in Table 1.

The wheat samples were collected twice a week during the growing season. Each sample consisted of ten subsamples (the upper half of the plants was collected) covering an area of about 0,2 hectare.

Macronutrients were analyzed with a method developed for trace elements. The wheat samples were dried at 60 °C and ground with a hammer mill (fitted with a 2 mm sieve). Plant samples of 5,00 grammes were weighed into a silica crucible and dried at 105 °C for 4 hours. The cooled sample was ashed in a muffle furnace at 450 °C overnight. The cooled ash was moistened with a small quantity of water and 10 ml of 6 N HCl was slowly added. The solution was evaporated to dryness on a water bath. To the dry crucible 40 ml of 0,2 N HCl was added and kept on the hot water bath, covered with watch glass, for about 30 minutes. The hot solution was filtered into a 100 ml volumetric flask. The filterpaper with the undissolved ash residue was ashed in the original silica crucible at 600 °C. The cooled residue was transferred into a teflon dish whereupon 0,2 ml concentrated $HClO_4$ and 5 ml concentrated HF were added. The dish was kept on an electric hot plate (200 °C) until all HF had been volatilized. To the teflon dish 0,5 ml 6 N HCl was added and kept on the hot plate until the hydrochloric acid was volatilized. The residue was dissolved over the hot plate in 5 ml 0,2 N HCl. This solution was added to the main solution in the 100 ml volumetric flask. The flask was made up to volume with 0,2 N HCl. Ca, K, and Mg were determined by atomic absorption, P by the molybdovanadate method (Gericke and Kurmies 1952).

Table 1. Properties of experimental soils as analyzed at sowing and at harvesting time.

	Soil type	$pH(H_2O)$	mg/l soil			
			Ca	K	Mg	P
Winter wheat						
Tikkurila	Sandy clay					
sowing		5,1	1 350	290	155	23,3
harvest		5,1	1 300	270	155	18,6
Mouhijärvi	Silty clay					
sowing		5,5	1 450	90	190	3,1
harvest		5,9	1 450	90	190	3,0
Spring wheat						
Tikkurila	Sand					
sowing		5,8	1 400	330	65	41,8
harvest		5,9	1 450	270	70	53,5
Mouhijärvi	Clayey silt					
sowing		5,3	750	120	140	2,2
harvest		5,5	850	100	160	1,8

Results of the plant analyses are given in Fig. 1. as moving averages of order three.

Calsium. The Ca contents of the wheat varied from 0,4—0,6 per cent in early spring to about 0,1 per cent near and at harvesting time (Fig. 1). No clear differences existed between the spring and winter wheat. Since different varieties were grown at Tikkurila and at Mouhijärvi, the varietal effects and effects of soil Ca contents on the Ca content of the plants can not be defined clearly. However, the Ca content of spring wheat grown at Tikkurila is about twice as high as that of the Mouhijärvi wheat. This may be due to a similar relationship between the exchangeable Ca contents of the respective soils (Table 1). In the case of winter wheat, the Ca contents of both the plants and the soils are almost equal.

Potassium. The K contents of wheat decreased from 3—5 per cent in the spring to 0,5—0,8 per cent in late summer. The differences between the spring and winter wheat are small. The exchangeable contents of K are clearly higher in Tikkurila soils than in Mouhijärvi soils. This difference is clearly reflected in the K contents of plants during their early growing stages but becomes less marked towards the end of the growing period.

Phosphorus. The shape of the curves indicating the contents of P in plants are very similar to those of K: beginning from 0,3—0,5 per cent in the spring and then decreasing to about the 0,2 per cent level towards August—September. The P contents of spring wheat are slightly higher than those of winter wheat. The considerably higher contents of soluble P in Tikkurila soils are clearly reflected as higher P contents in June for wheat grown in Tikkurila. In July this difference decreases until it disappears and even becomes slightly reversed during the later stages of growth.

Magnesium. The changes in the Mg contents of wheat during the growing period are not as marked as in the case of the other main nutrients. The tendency of the Mg contents to decrease is distinct (from about 0,2 to 0,1 per cent) only in the case of spring wheat grown at Mouhijärvi. The relative stability of the Mg contents of plants during the growing season as compared to other nutrients may partly be due to lesser Mg fertilization.

Macronutrient content of Finnish wheat. Data on the macronutrient content of wheat grown in Finland and elsewhere vary greatly. Among the factors causing this variation are the differences in soils, in the growing stage of wheat at sampling, in plant parts selected for analysis, and in analytical methods.

The contents of all four elements under study are normal if compared to results obtained in Finland (e.g. Kaila and Elonen 1970, Anon. 1978). Bergmann and Neubert (1976), referring to a number of studies conducted elsewhere, have presented Ca, K, and P contents of wheat which, at the tillering stage, are similar to those obtained in this study but somewhat higher at later stages. Their Mg contents generally exceed those of this study.

Stage of plant growth and sampling. For obtaining comparable results, sampling for plant analysis should be done at the same stage of plant growth. As stated above, the highest contents of macronutrients as well as the most distinct differences due to soil nutrient status existed at an early stage of plant growth, i.e. at the tillering stage. Later, during the stem extension stage, the contents as well as the differences decreased and reached their lowest values at the heading and ripening stages in late summer and early autumn. Therefore, due to higher contents and more distinct differences in materials sampled at early stages, analytical errors have less effect than in materials from late stages.

Obviously, the tillering stage, occurring in spring wheat during the month of June and early July, and in winter wheat about two weeks earlier, would be the best period for sampling. If possible, the sampling for plant analyses should be timed to the mid-tillering stage which in this experiment existed on June 20—25 for spring wheats and on about June 5—10 for winter wheats.

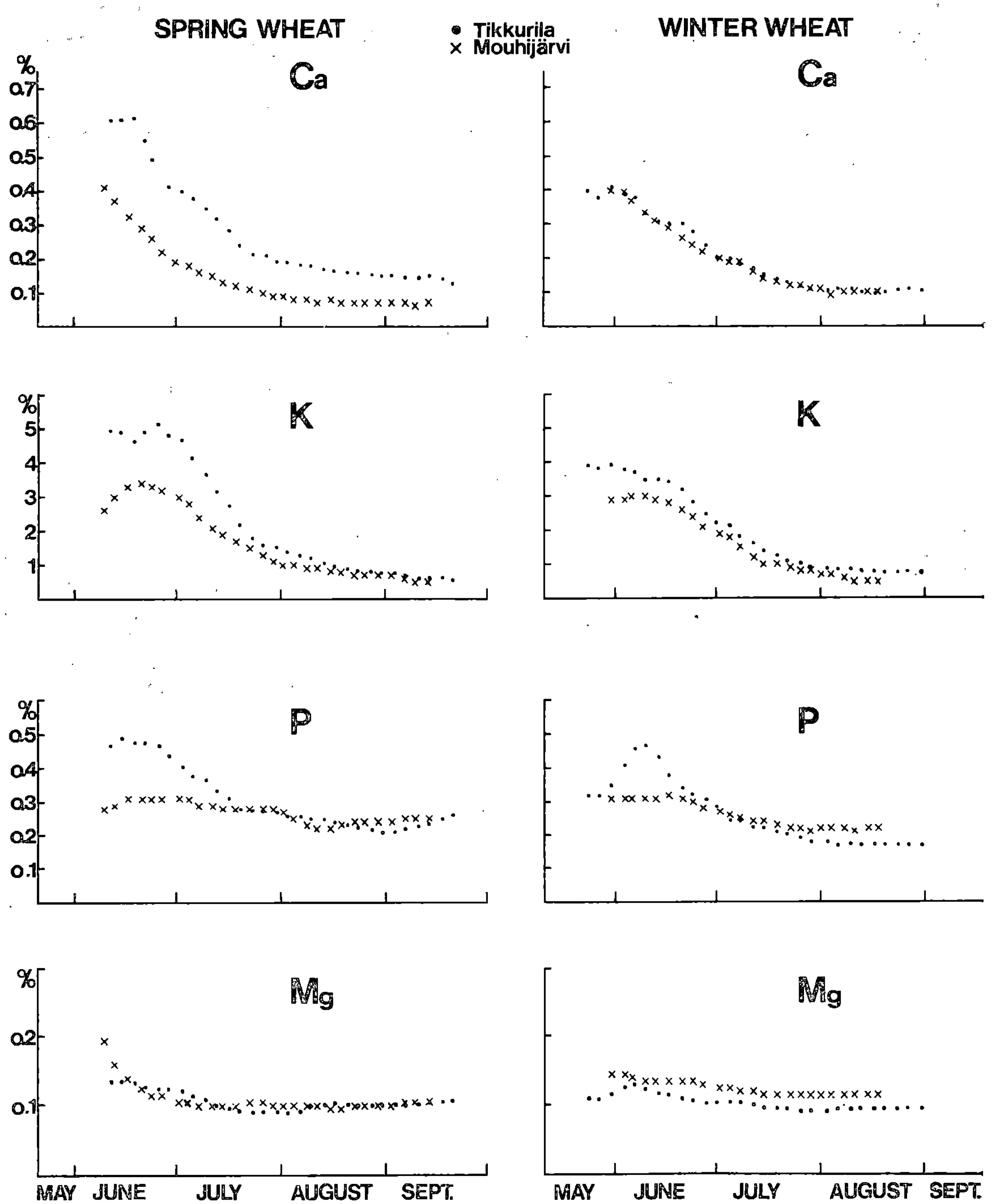

Fig. 1. Contents of Ca, K, P, and Mg during the growing season in spring and winter wheat grown at two locations.

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SELOSTUS

Vehnän makroravinnepitoisuuksien muutokset kasvukauden aikana

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Maatalouden tutkimuskeskus

Neljällä koekentällä kasvaneen kevät- ja syysvehnän Ca-, K-, P- ja Mg-pitoisuus analysoitiin kasvukauden aikana kahdesti viikossa. Tänä aikana ravinnepitoisuudet pienenivät huomattavasti: kalsiumpitoisuus 0,4—0,6 prosentista 0,1 prosenttiin, kaliumpitoisuus 3—5 prosentista 0,5—0,8 prosenttiin ja fosforipitoisuus 0,3—0,5 prosentista 0,2 prosenttiin. Magnesiumpitoisuuden lasku oli pienempi, 0,15 prosentista 0,1 prosenttiin.

Kevät- ja syysvehnän Ca-, K-, P- ja Mg-pitoisuuksien välillä ei havaittu selviä eroja. Maan makroravinnepitoisuuksien erot heijastuivat vehnän vastaaviin pitoisuuksiin. Vehnän ravinnepitoisuuksien erot olivat huomattavasti suuremmat kasvin varhaisessa kehitysvaiheessa kuin kasvukauden lopulla. Siksi arvioitaessa maan ravinteisuutta kasvianalyysin avulla, olisi näytteet otettava varhaisessa kasvuvaiheessa.

ANNALES AGRICULTURAE FENNIAE, VOL. 17: 163—174 (1978)
Seria ANIMALIA DOMESTICA N. 47 — Sarja KOTIELÄIMET n:o 47

FACTORS AFFECTING VOLUNTARY SILAGE INTAKE BY DAIRY COWS

ELSI ETTALA and MARTTI LAMPILA

ETTALA, E. & LAMPILA, M. 1978. **Factors affecting voluntary silage intake by dairy cows.** Ann. Agric. Fenn. 17: 163—174. (Agric. Res. Centre, North Savo Exp. Sta. 71750 Maaninka, Finland.)

The study comprised 13 feeding trials conducted in 1970—75 with altogether 296 Ayrshire cows. The cows received direct-cut silage *ad libitum*, 2 kg hay a day, and barley as the only concentrate-given at the rate 0, 1/3, 2/3, or 3/3 of the energy required for milk production exceeding 5, 7,5 or 10 kg 4 % FCM per cow per day.

On average, the total dry matter (DM) consumption (av. 13,0 kg) was composed of 73,6 % silage, 11,0 % hay and 15,4 % barley. Average daily intake of silage DM was 2,0±0,4 kg per 100 kg liveweight and of total DM 2,7±0,5 kg. Daily milk yield was on average 15,0±4,3 kg/cow.

The differences in intake between the cows were highly significant. Of the overall variation in intake, the percentage due to sets of all the independent variables studied was 57,2 % for direct-cut silage, 44,6 % for silage DM and 68,6 % for total DM. Changes in milk yield explained 6,5 % of the variation in silage DM intake, and changes in liveweight 5,1 %. The influence of the different factors was calculated on the basis of the within-cow variation.

The addition of one kilogram barley DM decreased silage DM intake by 638 g/cow per day, and increased total DM intake by 362 g. An increase in hay consumption decreased the intake of silage DM 1146 g/kg hay DM.

A rise of one percentage unit in silage DM increased the intake of silage DM and total DM by 169 g/cow per day. Increase in crude fibre and sugar contents decreased intake while increase in nitrogen content increased it. Increased acetic acid, ammonium nitrogen and soluble nitrogen contents decreased silage intake and a rise in pH increased it. Lactic acid, butyric acid and propionic acid did not exert a significant effect on intake.

Regression equations including the four most effective variables are calculated for the prediction of silage, silage DM and total DM intake.

Index words: silage, DM intake, dairy cows

INTRODUCTION

Relatively favourable, climatological conditions for forage production in Finland have been and are the basis for continuous efforts towards abundant use of forages in the feeding of cattle. They include measures taken for increasing the net energy and protein contents of the crops by early harvesting for silage. Recent development in the technology of harvesting and ensiling has essentially facilitated this trend.

The studies of JÄNTTI (1968) revealed technical and economical possibilities for improved production of grass crops by means of increased nitrogen fertilization. As a result, an extensive study on the whole subject was started in 1969. In this context, studies on the feeding and nutrition of cattle have largely dealt with the protein supply to dairy cows, which is essentially dependent on the voluntary intake of silage. Results of this work have been preliminarily publish in several reports (ETTALA et al. 1974, 1975 a and b, 1978, ETTALA 1976). The present paper summarizes those results concerning factors affecting voluntary silage and total dry matter intake.

MATERIAL AND METHODS

Experimental animals

This study comprised 13 feeding trials made with altogether 296 Ayrshire cows. Five trials were made at the Jokioinen Estate (1970—1975, 182 cows), five at the North Savo Experimental Station (1970—1975, 80 cows) and three at the Häme Experimental Station (1970—1973, 34 cows). The length of the trial period ranged from 60 to 155 days (mean 102 days). The mean time elapsed since calving was 91 days at the beginning of the trial period and 193 at the end. The cows were weighed before the afternoon feeding on two successive days at the beginning and end of the trial and at intervals of 30 days during the trial period.

Feeding

Feed rations comprised 2 kg hay, barley as the only concentrate, mineral mixtures, and silage offered *ad libitum*. Barley was given at the rate of 0, 1/3, 2/3 or 3/3 of the energy requirement for milk production in excess of 5, 7,5 or 10 kg daily yield. Energy requirement for production was estimated at 0,4 feed unit (= renewed Scandinavian feed unit, s.f.u., which equals 0,7 kg Starch Equivalent) per kg 4 percent fat-corrected milk (FCM). Protein allowance was 60 g digestible crude protein (DCP) per kg FMC. Daily maintenance requirements were estimated at 3,8 s.f.u. and 320 g DCP per 500 kg liveweight (POIJÄRVI 1925, 1947).

The cows were fed twice a day with individually weighed portions. In the Jokioinen trials the daily eating time was about 6,5 h — ca. 3 h in the morning and ca. 3,5 h in the afternoon. In the other trials, silage was available at all times. Feed intake was determined by weighing feed residues.

Silages

The silages were prepared from grass sward given nitrogen fertilizer at different rates, chiefly ca. 100 kg N/ha per cutting (ETTALA et. al. 1974, 1975 a). The forage was cut with a forage harvester and ensiled with acids or with additives containing acid and formaldehyde (ETTALA et al. 1975 a). The silages were stored in tower silos with a capacity of 50—100 tons. The main part of the herbage was ensiled in early summer, but part, stored in the same towers, was harvested in mid summer or the autumn.

The trial feeding began in Ocktober—November (9 trials) or December—January (4 trials). The shortest time between the preparation of the silage and the start of feeding was 38 days while the longest time at the end of feeding was 324 days. On average, trial feeding began 97 days after the preparation of the silage and ended 258 days after its preparation.

Analytical methods and sampling

Samples of the barley and hay were taken each day, combined to represent a month's feed, and subjected to standard feed analysis.

Silage samples (taken fortnightly) represented about a 0,5 m layer of forage to be fed during the next two weeks. Samples were taken at three sampling points: close to the silo wall, at the silo centre, and halfway between these. They were pooled and a representative sample was taken for analysis.

Dry matter content was determined by drying at 105 °C and the values were corrected by adding 100 % of the butyric and propionic acids and 80 % of the acetic acid (JARL and HELLEDAY 1948, NORDFELDT 1955). The conventional feed analysis was performed by standard methods. Volatile fatty acids, lactic acid, ammonium-N, cold water soluble N and sugar were determined on an aqueous extract of fresh silage. Fatty acids were determined by gas-liquid chromatography (HUIDA 1973); lactic acid (BARKER and SUMMERSON 1941) and ammonium-N colourimetrically (MCCULLOUGH 1967); soluble N by the Kjeldahl method, and sugar, expressed as glucose, by the method of SOMOGYI (1945) as modified by SALO (1965). Silage pH was determined electrometrically. The milk production of each cow was weighed separately at every milking. Milk samples representing the 2-day production of each cow were analysed every 5 days for fat and every 10 days for protein and lactose (ETTALA 1976).

Statistical methods

The records for the voluntary feed intake and milk production were combined for the same fortnightly periods for which the composition and properties of silages were determined.

The effect of the different factors on the feed intake was estimated by applying methods for simple correlations, least squares analysis of variance (HARVEY 1966), and stepwise regression analysis (DRAPER and SMITH 1966). Thus, as well as simple correlations, it was possible to estimate variations due to separate factors independently of each other. It was also possible to estimate the proportion of the total variation in intake explained by the regression model containing the statistically significant independent variables. The effect on intake of the properties of the individual cows was elucidated by using the least squares analysis of variance to divide the total variation into between-cow and within-cow parts. The effect of the other factors was calculated on the basis of the within-cow variation.

RESULTS AND DISCUSSION

Voluntary feed intake and its variation

The intake of silage was 41,2±7,7 kg, or, of silage dry matter (DM), 9,4±1,8 kg/cow per day, or 2,0±0,4 kg/100 kg liveweight per day (Table 1). The contribution of silage to the total DM intake was 73,6±10,3 %. The total intake of DM was 13,0±2,5 kg/cow per day, or 2,7±0,5 kg/100 kg liveweight per day. This average figure lies around the middle of the range of intake values reported from corresponding feeding trials, 2,4—3,2 kg DM/100 kg liveweight per day (GASTLE and WATSON 1969, 1970, 1973, 1974, 1975, DIJKSTRA 1958, EKERN 1972, MURDOCK and HODGSON 1967).

The variation in the intake of silage was remarkably wide (Table 1). When calculated according to two standard deviations (95 %) the lower and upper confidence limits were, respectively, for the intake of silage — 25,8 and 56,6 kg/head per day; for the intake of silage DM — 5,8 and 13,00 kg and for the intake of total DM — 8,0 and 18,0 kg. These values are means for two week periods. These limits range 37—38 % under and over the means. The maximum five-day mean for the intake of silage DM was 15,8 kg/cow per day, (3,13 kg/100 kg liveweight per day) and for the total intake of DM 21,1 kg/cow per day (3,86 kg/100 kg liveweight per day).

In the trials of EKERN (1972), the intake of »converted roughage» DM by the best cows was 20—30 % higher than the corresponding

Table 1. Means and deviations of properties of cows and feeds, and of feed intake.

Properties	5 experiments Jokioinen		5 experiments North Savo		3 experiments Häme		Total	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Properties of cows								
Liveweight, kg	488	48,9	455	49,0	493	50,4	477	51,7
Milk yield, 4 % FCM kg/day	16,6	4,1	15,0	4,3	15,0	4,5	15,9	4,3
Days from calving	135	42,5	166	63,0	167	66,1	149	55,4
Number of lactation periods	2,8	1,6	3,3	2,1	3,7	2,2	3,0	1,9
Properties of silages								
DM, %	24,9	2,7	21,5	2,5	20,7	1,3	23,3	3,1
Crude fibre, % in DM	26,8	3,6	27,7	3,9	27,5	3,1	27,2	3,7
Nitrogen, % in DM	2,9	0,4	3,3	0,4	3,3	0,3	3,1	0,5
Sugar, % in DM	4,8	3,3	5,8	5,9	8,2	4,8	5,5	4,6
pH	4,2	0,2	4,4	0,4	4,3	0,2	4,3	0,3
Lactic acid, % in DM	6,2	3,3	4,3	3,1	3,1	2,9	5,2	3,4
Acetic acid, % in DM	1,5	0,7	1,5	1,0	1,3	1,2	1,4	0,9
Propionic acid, % in DM	0,2	0,2	0,2	0,3	0,3	0,3	0,2	0,2
Butyric acid, % in DM	0,12	0,62	0,04	0,28	0,00	0,00	0,08	0,49
Soluble N, % of total N	47,2	7,5	44,7	15,0	44,6	4,3	46,1	10,7
NH_3 -N, % of total N	4,1	1,5	3,9	2,4	2,7	1,5	3,9	1,9
Intake per cow per day								
Silage, kg	41,2	6,3	39,1	8,6	48,9	6,2	41,2	7,7
» kg DM	10,1	1,7	8,2	1,5	10,0	1,4	9,4	1,8
» kg DM/100 kg livewt.	2,1	0,35	1,8	0,4	2,0	0,2	2,0	0,4
» g DM/kg $W^{0.75}$	98	15,8	84	15,9	96	11,2	93	16,8
Barley, kg DM	2,3	1,8	2,0	1,7	1,5	1,1	2,1	1,7
Hay, kg DM	1,5	0,2	1,2	0,4	1,4	0,3	1,4	0,3
Total DM, kg	14,0	2,0	11,4	2,4	13,0	2,1	13,0	2,5
» DM, kg/100 kg livewt.	2,9	0,4	2,5	0,5	2,6	0,4	2,7	0,5
» DM, g/kg $W^{0.75}$	135	19,1	116	23,3	124	17,6	127	22,4
Silage, % of DM of ration	73,0	10,2	73,2	10,8	78,0	7,3	73,6	10,3
Roughage, % of DM of ration	84,0	10,9	84,1	11,7	89,0	7,7	84,6	11,1

average of this study, and the intake by the poorest cows was 10—40 % lower. In the study of STONE et al. (1960), the corresponding values were 26 % and 20 % for the intake of direct-cut silage and 34 % and 52 % for the intake of roughage.

The intake of silage was higher when eating time was limited (at Jokioinen, Table 1), which indicates that the daily eating time of 6,5 hours was sufficient. Possible effects of differences in that time were eliminated in the treatment of the results.

Effects of properties of the animals on intake

The liveweight of the cows was 477±51,7 kg and the daily milk yield 15,9±4,3 kg (Table 1). These properties of the cows had the greatest effect on intake (Tables 3 and 4).

Table 2. Simple correlations between silage intake and properties of cows and feeds (296 cows, 2094 observations).

Properties	Intake of silage per cow per day	
	g/kg $W^{0.75}$	DM g/kg $W^{0.75}$
Properties of cows		
Liveweight, kg	—0,08	—0,02
Milk yield, 4 % FCM kg/day	+0,26***	+0,12*
Days from calving	—0,21***	—0,10
Number of lactation periods	—0,01	—0,07
Properties of silages		
DM, %	—0,34***	+0,41***
Crude fibre, % in DM	—0,11*	—0,37***
Nitrogen, % in DM	+0,14*	—0,02
Sugar, % in DM	+0,25***	+0,05
pH	+0,16**	—0,12*
Lactic acid, % in DM	—0,11*	+0,18*
Acetic acid, % in DM	—0,09	—0,05
Propionic acid, % in DM	+0,06	—0,09
Butyric acid, % in DM	+0,02	+0,01
Soluble N, % of total N	—0,13*	—0,08
NH_3 -N, % of total N	—0,20***	—0,11*

* $P < 0,05$, ** $P < 0,01$, *** $P < 0,001$.

Table 3. Effect of variation in properties of cows and feeds on feed intake as revealed by least squares analysis of variance. Within-cow variation.

Properties	Silage per cow per day						Total DM per cow per day			
	kg		DM kg		DM g/kg $W^{0.75}$		kg		g/kg $W^{0.75}$	
	F	R^2 %	F	R^2 %	F	R^2 %	F	R^2 %	F	R^2 %
Regression variables										
Liveweight, kg	***	2,04	***	2,11	**	0,19	***	1,20	NS	0,00
Milk yield, 4 % FCM kg/day	***	2,05	***	1,88	***	2,52	***	1,07	***	1,49
Days from calving	***	1,61	***	1,44	***	1,86	***	0,82	***	1,11
Square of days from calving	***	2,76	***	2,58	***	3,27	***	1,47	***	2,02
Barley, kg DM per cow per day	***	0,98	***	0,89	***	1,21	***	0,83	***	1,01
Hay, kg DM per cow per day	***	3,25	***	2,66	***	3,20	***	0,11	***	0,16
Silage										
DM, %	***	5,67	***	2,11	***	2,45	***	1,20	***	1,55
crude fibre, % in DM	***	0,54	***	0,40	***	0,50	***	0,23	***	0,30
nitrogen, % in DM	***	0,49	***	0,24	***	0,33	***	0,14	***	0,23
sugar, % in DM	***	0,25	**	0,14	**	0,16	**	0,08	**	0,10
pH	***	0,21	*	0,10	*	0,11	*	0,06	*	0,05
lactic acid, % in DM	NS	0,01	NS	0,03	NS	0,02	NS	0,01	NS	0,02
acetic acid, % in DM	***	0,34	**	0,16	**	0,17	**	0,09	**	0,10
propionic acid, % in DM	NS	0,00	NS	0,01	NS	0,01	NS	0,00	NS	0,01
butyric acid, % in DM	NS	0,07	NS	0,03	NS	0,05	NS	0,02	NS	0,03
soluble N, % in DM	***	0,21	***	0,26	***	0,36	***	0,15	***	0,23
NH_3 -N, % in DM	***	0,26	**	0,14	**	0,18	**	0,08	**	0,11
Factors										
Concentrate levels	***	0,77	***	0,85	***	1,05	***	0,48	***	0,62
Number of lactation periods	***	0,40	**	0,34	***	0,52	**	0,19	***	0,33
Trial localities	***	3,26	***	2,53	***	2,82	***	1,44	***	1,75
Differences among individual cows, n = 296										
Sums of squares due to cows:										
between-cow	70741		4421,7		0,3258		9943,1		0,7784	
within-cow	53562		2949,6		0,2032		6214,0		0,4133	
error	26933		1365,6		0,1353		1365,6		0,1351	
F	4,05***		6,84***		5,94***		17,34***		17,68***	

NS, no significant; *P < 0,05, **P < 0,01, ***P < 0,001.

The variation in *liveweight* explained 3,7 %, 5,1 % and 2,9 % of the variation in intake of silage, silage DM and total DM, respectively, when the influence of the other factors significant for intake had been eliminated (Table 4). A liveweight increase of one kilogram raised the daily intake of silage by 79 g, and those of silage DM and total DM by 19 g. When intake was calculated per kg metabolic weight, the effect was very small (Tables 2 and 3).

Close positive correlations have usually been found between liveweight and feed intake (Foot and Line 1966, Hyppölä and Hasunen 1970, Mather et al. 1960, McCullough 1961, Skovborg and Andersen 1973). In the study of Kestler et al. (1968) the relation between liveweight and roughage intake varied with the breed.

The variation in *milk production* exerted a somewhat stronger effect on intake than changes in liveweight. R^2 is 4,9, 6,5 and 3,7 % for silage, silage DM and total DM, respectively (Table 4). Extra production of one kilogram of 4 % FCM increased the daily intake of silage per cow by 1,2 kg and the intakes of silage DM and total DM by 273 g.

In other studies the relationship between milk yield and roughage intake has varied. Johnson et al. (1966), McCullough (1961) and Stone et al. (1960) found a strong positive correlation,

Table 4. Variation in intake of silage and total DM as explained by the factors exerting a significant effect on intake. Within-cow variation.

Properties	Silage per cow per day						Total DM per cow per day		
	kg			DM kg			kg		
	b	t-value	R^2 %	b	t-value	R^2 %	b	t-value	R^2 %
Properties of cows									
Liveweight, kg	+0,079	+12,7***	3,7	+0,019	+13,2***	5,1	+0,019	+13,2***	2,9
Milk yield, 4 % FCM kg/day	+1,197	+14,6***	4,9	+0,273	+14,8***	6,5	+0,273	+14,8***	3,7
Days from calving ..	+0,089	+ 9,3***	2,0	+0,019	+ 8,7***	2,2	+0,019	+ 8,7***	1,3
Square of days from calving	—0,0003	—12,2***	3,4	—0,00007	—11,9***	4,2	—0,00007	—11,9***	2,4
Number of lactation periods	—0,771	— 4,3***	0,4	—0,169	— 4,2***	0,5	—0,169	— 4,2***	0,3
Other feeds									
Barley, kg DM per cow per day	—2,724	—13,4***	4,1	—0,638	—13,9***	5,7	+0,362	+ 7,9***	1,0
Hay, kg DM per cow per day	—5,525	—12,1***	3,3	—1,146	—11,1***	3,6	—0,146	— 1,4 NS	0,0
Properties of silages									
DM, %	—1,110	—18,0***	7,4	+0,169	+12,1***	4,3	+0,169	+12,1***	2,5
Nitrogen, % in DM .	+2,026	+ 5,7***	0,7	+0,361	+ 4,5***	0,6	+0,361	+ 4,5***	0,3
Crude fibre, % in DM	—0,226	— 4,7***	0,5	—0,039	— 3,6***	0,4	—0,039	— 3,6***	0,2
Sugar, % in DM	—0,160	— 4,3***	0,4	—0,025	— 3,0**	0,3	—0,025	— 3,0**	0,1
Acetic acid, % in DM	—1,022	— 5,4***	0,7	—0,181	— 4,2***	0,5	—0,181	— 4,2***	0,3
pH	+2,108	+ 4,2***	0,4	+0,364	+ 3,2**	0,3	+0,364	+ 3,2**	0,2
Soluble N, % in DM .	—1,192	— 3,1**	0,2	—0,322	— 3,7***	0,4	—0,322	— 3,7***	0,2
NH_3 -N, % in DM ..	—8,222	— 3,4***	0,3	—1,320	— 2,4*	0,2	—1,320	— 2,4*	0,1
Total			57,2			44,6			68,6

Ns, not significant; *P < 0,05, **P < 0,01, ***P < 0,001. Differences between the trial localities were eliminated.

and Skovborg and Andersen (1973) a somewhat weaker one. Kestler et al. (1968) did not observe any significant relation, and in their review of the literature Hyppölä and Hasunen (1970) came to the conclusion that a rise in the milk yield cause a slight increase in the intake of converted DM. Ekern (1972) found a negative correlation between milk yield and the intake of »converted roughage» at the initial stage of lactation, which changed to a positive correlation 14 weeks after calving.

The stage of lactation had a curvilinear effect on the feed intake, when the influence of the other factors was eliminated (Table 4). No elimination was performed in the studies of Ekern (1972) in which the intake of »converted roughage» was greatest 16 weeks after calving under normal feeding and ca. 18—19 weeks after calving under high-concentrate feeding. Johnson et al. (1966) found that the intake of roughage increased to about the 15th week of lactation and then remained fairly constant. Hutton (1963) reported that intake generally rose up to the 21st week.

The effect of *lactation number* was relatively slight when the influence of milk yield and liveweight was eliminated (Tables 3 and 4). When no elimination was performed, the intake was greatest in the second and third lactations (Table 5).

Individual differences in intake were highly significant after the influence of all the other factors was eliminated (Table 3, bottom).

Large differences in intake between individual cows have been reported in many other studies (Coppock et al. 1974, Ekern 1972, Foot and Line 1966, Johnson et al. 1966, Stone et al. 1960, Wictorsson 1973, Wictorsson and Bengtsson 1973). Kress (1970) and Kress

Table 5. Mean silage and total DM intake by cows in different lactation periods.

Item / Observations	Lactation periods 1	2	3	4	5	6 ≦
Observations	454	580	366	292	179	223
Liveweight, kg	438	472	498	494	493	499
Milk yield, 4 % FCM kg/day	14,5	16,9	16,8	16,0	15,0	15,1
Silage per cow per day						
kg	36,9	42,6	43,1	42,3	41,6	41,7
DM, kg	8,5	9,7	10,3	9,6	9,1	9,4
DM, kg/100 kg livewt.	1,96	2,06	2,07	1,94	1,85	1,88
DM, g/kg $W^{0.75}$	89	96	97	92	87	89
Total DM per cow per day						
kg	11,7	13,5	14,0	13,0	12,4	12,8
kg/100 kg livewt.	2,68	2,87	2,82	2,64	2,53	2,56
g/kg $W^{0.75}$	122	133	133	124	119	121

et al. (1971) observed that feed consumption is affected by the joint influence of genotype and environmental factors. Mather (1959) examined repeatabilities of roughage consumption obtained from different studies and found that they ranged from 0,22 to 0,55 when intakes for 3—4 weeks were compared between different years. The repeatability of silage intake was 0,55. Rimm (1963) obtained roughage intake repeatabilities of $0{,}21 \pm 0{,}14$ and $0{,}27 \pm 0{,}12$, and h^2 values of $0{,}31 \pm 0{,}33$ and $0{,}29 \pm 0{,}35$. England (1962) obtained an h^2 value of 0,384 for the daily feed consumption by cattle.

The above studies indicate that the capacity for roughage consumption may be a partly inheritable property, which could be improved by selective breeding.

Effect of other feeds on intake

The cows consumed on average of $2{,}1 \pm 1{,}7$ kg of barley DM and 1,4 kg$\pm$0,3 kg of hay DM per day (Table 1).

The effect of the *barley* supplement on intake was highly significant both in respect of the concentrate levels given for the same milk production (Table 3, factors) and the allowance determined according to milk production (Table 3, regression variables). The combined influence of barley intake is given in Table 4. An increase of one kilogram DM in the barley intake decreased the intake of silage DM by 638 g/cow per day.

In other studys the decrease has most usually ranged from about 0,2 to 1,0 kg DM/kg concentrate DM (Campling and Murdoch 1966, Castle and Watson 1975, Foot and Line 1966, Forbes and Irwin 1970, Mather et al. 1960, McCullough 1961, Murdock and Hodgson 1967, Wilkinson 1969). Ekern (1972) reported that concentrates decreased roughage intake more at the initial stage of lactation (ca. 0,9 kg DM/kg DM) than at the middle stage (0,5—0,3 kg DM/kg DM). Mäkelä (1956) came to the conclusion that each kilogram of concentrate consumed decreased the intake of roughage by 0,5 kg.

Total intake of DM increased by 362 g for each kg of barley DM consumed per cow per day (Table 4). Kesler and Spahr (1964) noted that the energy intake was greatest and Wictorsson and Bengtsson (1973) reported maximum consumption of DM when ca. 45—60 % of total DM intake consisted of concentrates.

An increase in *hay consumption* decreased the intake of silage DM by slightly more than what was received from the hay (1146 g/kg hay DM), but the decrease in the total intake of DM was not significant. Variation in the hay intake was small, however, due to its constant supply.

Increased hay consumption has not decreased silage intake with less bulky diets as sharply as here. McCullough (1961) and Murdock and Hodgson (1967) reported that one kilogram of hay DM decreased the daily intake of silage DM by only 0,3—0,7 kg.

Effect of silage composition on intake

Data on the composition of silages are given in Table 1.

The effect of *silage DM content* (23,3±3,1 %) on intake was highly significant (Tables 2, 3 and 4). An increase in DM content of one percentage unit decreased the intake of silage by ca. 1,1 kg but increased silage DM and total DM intake by 169 g (Table 4).

A rise in DM content has generally been observed to increase the intake of silage DM (Christiansen et al. 1971, Gordon et al. 1961, 1964, Harris et al. 1966, Hoffman et al. 1970, Jackson and Forbes 1970, Kirchgessner et al. 1972, McCullough 1961, Presthegge 1959, Skovborg and Andersen 1973, Thomas et al. 1961, Ward et al. 1966, Wellman 1966, Wilkins et al. 1971). However, this result has not been obtained in all trials (Ekern 1972, Ettala et al. 1975 b). Thomas et al. (1961) came to the conclusion that the effect of the DM content on intake is partly indirect, since it influences silage fermentation.

An increase in *silage fibre content* (27,2±3,7 % in DM) caused a highly significant decrease in the intake of silage, silage DM and total DM (Tables 3 and 4). In other trials also, a rise in the fibre content or in cell-wall substances in general has decreased intake (Berner 1959, Christiansen et al. 1971, McCullough 1961, 1962, Van Soest 1965, Wilson and McCarrick 1966).

An increase in *silage nitrogen content* (3,1±0,5 % in DM) was found to increase intake, when its effect considered alone (Table 4). When the effect of other factors was taken into account, it caused a significant increase only in the intake of fresh silage (Table 2).

McCullough (1961) and Wilkins et al. (1971) also observed that a rise in silage nitrogen content increased silage intake. In some studies, a marked rise in protein content has decreased intake to some extent (Castle and Watson 1969, Ettala et al. 1974, McCullough 1962), which is presumably connected with differences in the fermentation occurring in protein-rich and protein-poor silages (Ettala et al. 1974, Gordon et al. 1964).

An increase in *silage sugar content* (5,5±4,6 % DM) decreased intake, when the effect of the other properties was eliminated (Table 4), but when no adjustment was made, increased sugar raised fresh silage intake (Table 2).

Effect of silage quality on intake

The quality of silages was generally very good (Table 1). The properties reflecting silage fermentation and quality had a smaller effect on silage intake than the factors of the other groups (Tables 2, 3 and 4).

pH, *lactic acid* and silage sugar contents were closely connected with each other and with the other fermentation products (Table 6). Therefore their effect on intake depended largely on whether the influence of the other factors had been eliminated or not (Tables 2, 3 and 4). When this had been done, lactic acid did not exert a significant effect on intake (Table 3).

Lactic acid has been found to increase intake (Gordon et al. 1964, Kirchgessner et al. 1972, Wilkins et al. 1971), or to have a curvilinear relationship with it (Jackson and Forbes 1970) or to have no significant effect (Gordon et al. 1961). High total acidity has also been observed to decrease intake significantly (Gordon et al. 1961, Wilkins et al. 1971).

The effect of pH on intake has been variable; a rise in pH has both increased (Brown and Radcliffe 1972) and decreased intake (Gordon et al. 1964, McCullough 1961), or not affected it at all (Gordon et al. 1961, Wilkins et al. 1971). This variability may be explained by the fact that a high pH can be an indication of both limited fermentation and undesirable fermentation.

Table 6. Coefficients of correlation (r) between properties of silage.

	% in DM			pH	% in DM					
	Crude fibre	Nitrogen	Sugar		Acetic acid	Propionic acid	Butyric acid	Lactic acid	Soluble N	NH_3 N
DM, %	—0,36	—0,18	—0,24	—0,36	+0,04	—0,21	—0,01	+0,38	+0,08	+0,11
Crude fibre, % in DM		—0,49	—0,31	+0,11	+0,13	+0,07	+0,17	—0,13	—0,28	+0,09
Nitrogen, % in DM			+0,13	+0,25	+0,09	+0,01	—0,19	—0,09	+0,50	+0,19
Sugar, % in DM				+0,15	—0,66	+0,33	—0,13	—0,67	—0,18	—0,58
pH					+0,22	+0,09	+0,22	—0,20	—0,21	+0,24
Acetic acid, % in DM						—0,15	+0,20	+0,55	+0,14	+0,64
Propionic acid, % in DM							+0,01	—0,40	—0,06	—0,12
Butyric acid, % in DM								+0,04	—0,11	+0,24
Lactic acid, % in DM									+0,17	+0,42
Soluble N, % in DM										+0,39

$P < 0{,}05$, $r \gtrless 0{,}05$; $P < 0{,}01$, $r \gtrless 0{,}06$; $P < 0{,}001$, $r \gtrless 0{,}08$.

The effect of pH on intake in the present work should apparently be explained differently because of the use of acid-formaldehyde mixtures as preservative for part of the silages. Then high pH and low lactic acid content indicate a low total fermentation caused by formaldehyde while low pH and high lactic acid in these silages are an indication of a secondary fermentation.

Acetic acid, *ammonium nitrogen* and *soluble nitrogen* decreased silage intake significantly (Table 4) although present in only small amounts in the silages (Table 1). The same effect of acetic acid and/or ammonium nitrogen has been found in many other studies (Brown and Radcliffe 1972, Gordon et al. 1961, 1964, Jackson and Forbes 1970, Wilkins et al. 1971).

Butyric acid and *propionic acid* did not affect intake significantly (Table 3), presumably because the quantities present in the feed were small (Table 1). In some studies significant decreases in intake have been caused by butyric acid (Gordon et al. 1964, Kirchgessner et al. 1972) and propionic acid (Brown and Radcliffe 1972, Gordon et al. 1961, 1964).

Prediction of intake

In the case of within-cow variation, all the above factors explained 57,2, 44,6 and 68,6 percent of the variation in intake of silage, silage DM and total DM, respectively (Table 7).

Table 7. Increase in coefficient of determination for feed intake with stepwise addition of groups of variables. Within-cow variation.

	R^2 %		
	Silage per cow per day		DM per cow per day
	kg	DM kg	kg
Properties of cows +	39,5	18,9	61,5
other feeds +	45,8	32,5	61,8
composition of silage +	55,0	42,5	67,4
quality of silage	57,2	44,6	68,6

Differences between the trial localities were eliminated.

In practice, it is not possible to estimate the effect of many factors on intake. Therefore, an attempt is made here to predict intake on the basis of liveweight, milk yield, concentrate supply and silage DM content. The regression equations applicable to the present material are then as follows:

$$y_1 = 19{,}75 + 0{,}0495x_1 + 1{,}51x_2 - 3{,}365x_3 - 0{,}82x_4$$
$$y_2 = -5{,}34 + 0{,}0114x_1 + 0{,}354x_2 - 0{,}795x_3 + 0{,}226x_4$$
$$y_3 = -5{,}05 + 0{,}0127x_1 + 0{,}369x_2 + 0{,}176x_3 + 0{,}247x_4$$

where

y_1 = silage intake, kg per cow per day

y_2 = intake of silage DM, kg per cow per day

y_3 = total DM intake, kg per cow per day

and

x_1 = liveweight, kg

x_2 = milk production, 4 % FCM per cow per day

x_3 = barley intake, kg DM per cow per day

x_4 = DM content of silage, %

These variables explained 42,3, 48,7 and 70,8 percent of the variation in intake of silage, silage DM and total DM, respectively. The among-cow variation is included in these coefficients.

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SELOSTUS

Lehmien säilörehun syöntiin vaikuttavista tekijöistä

Elsi Ettala ja Martti Lampila

Maatalouden tutkimuskeskus

Säilörehun syöntiin vaikuttavia tekijöitä selvitettiin vuosina 1970—75 tehtyjen 13 ruokintakokeen tulosten perusteella. Kokeissa oli kaikkiaan 296 lehmää.

Lehmät saivat vapaasti säilörehua, 2 kg päivässä heinää sekä väkirehuna ohraa sen verran, että se vastasi joko 5, 7,5 tai 10 maitokiloa (4 %) ylittävän tuotannon aiheuttamasta energian tarpeesta joko 0, 1/3, 2/3 tai 3/3. Keskimääräisestä kuiva-aineen koko syöntimäärästä oli 73,6 % säilörehua, 11,0 % heinää ja 15,4 % ohraa. Lehmät söivät säilörehua 41,2±7,7 kg, säilörehun kuiva-ainetta 9,4±1,8 kg ja kuiva-ainetta kaikkiaan 13,0±2,5 kg päivässä. 100 elopainokiloa kohti säilörehun kuiva-aineen syönti oli 2,0±0,4 kg ja kuiva-aineen koko syönti 2,7±0,05 kg.

Tutkittujen tekijöiden vaihtelut selittivät yhdessä 57,2 % tuoreen säilörehun, 44,6 % säilörehun kuiva-aineen ja 68,6 % kuiva-aineen syönnin koko vaihtelusta. Maitomäärän muuttuminen selitti 6,5 % ja elopainon muutokset 5,1 % säilörehun kuiva-aineen syönnin vaihtelusta. Eri tekijöiden vaikutus laskettiin lehmien sisäiseen muunteluun perustuen. Lehmien väliset syöntierot olivat merkitseviä.

Ohran syönnin lisääntyminen yhdellä kuiva-ainekilolla vähensi säilörehun kuiva-aineen syöntiä 638 g ja lisäsi koko kuiva-aineen syöntiä 363 g lehmää kohti päivässä. Heinän kuiva-ainekilon lisäys vähensi säilörehun kuiva-aineen syöntiä 1 146 g.

Säilörehun kuiva-ainepitoisuuden kohoaminen yhdellä prosenttiyksiköllä lisäsi säilörehun kuiva-aineen ja koko kuiva-aineen syöntiä 169 g lehmää kohti päivässä. Säilörehun raakakuitupitoisuuden ja sokeripitoisuuden nousu vähensi ja typpipitoisuuden nousu lisäsi säilörehun syöntiä. Etikkahapon, ammoniumtypen ja liukoisen typen lisääntyminen vähensi säilörehun syöntiä ja pH:n nousu lisäsi sitä. Maitohappo, voihappo ja propionihappo eivät vaikuttaneet säilörehun syöntiin merkitsevästi.

ANNALES AGRICULTURAE FENNIAE, VOL. 17: 175—185 (1978)
Seria ANIMALIA DOMESTICA N. 48 — Sarja KOTIELÄIMET n:o 48

EFFECT OF CONCENTRATE FEEDING LEVEL IN GRASS SILAGE-BASED DIETS ON MILK PRODUCTION OF DAIRY COWS

ELSI ETTALA, MARTTI LAMPILA and HEIKKI RISSANEN

ETTALA, E., LAMPILA, M. & RISSANEN, H. 1978. **Effect of concentrate feeding level in grass silage-based diets on milk production of dairy cows.** Ann. Agric. Fenn. 17: 175—185. (Agric. Res. Centre, North Savo Exp. Sta. 71750 Maaninka, Finland).

The study comprised five feeding trials with altogether 182 Ayrshire cows in 1970—75. The cows received direct-cut silage *ad libitum*, 2 kg hay a day, and barley as the only concentrate-given at the rate 0, 1/3, 2/3 or 3/3 of the energy required for milk production exceeding 5, 7,5 or 10 kg 4 % FCM per cow per day.

On average, barley constituted 17 % of the dry matter intake, silage 72 % and hay 11 %. The silage intake decreased and the total dry matter intake rose with increasing barley feeding levels. Calculated from results for the highest and lowest supply levels in each trial, the changes in the intake of silage DM and total DM were —490 g and +550 g per cow per day per kg barley DM, respectively.

Milk production rose with an increase in barley supply level. Calculated from the production at the highest and lowest levels in each trial, the average increase was 730 g 4 % FCM per cow per day per kg barley DM. Significant changes in milk composition were found only in lactose content. Liveweight changes were small and irregular.

Index words: concentrate feeding, silage, milk production, dairy cows

INTRODUCTION

Attempts have been made in Finland to alleviate the shortage of protein in the dairy cow's rations by abundant feeding of high-protein grass silage. Possibilities are limited, however, by the fact that the increase in concentrate supply needed with increasing milk yield reduces silage intake. Therefore, especially at higher levels of milk production, a balance between silage and concentrate intake should be found where both protein and energy requirements are properly satisfied.

The subject has been studied in a series of experiments, the results of which, in regard to voluntary silage intake, have been presented in another paper (ETTALA and LAMPILA, 1978). This paper contains those results concerning the effect of concentrate supply on milk production and related matters.

Experimental animals and arrangements

Five feeding trials were conducted at the Jokioinen Estate in 1970—1975 with altogether 182 Ayrshire cows.

The time elapsed since calving at the beginning and end of the trials was, in different experiments, as follows:

Trials	Year	Average time from calving, days	Trial period, days
1	1970—71	79—189	110
2	1971—72	73—153	80
3	1972—73	81—186	105
4	1973—74	95—155	60
5	1974—75	69—154	85
Mean		79—167	88

The trials were conducted according to a factorial design with concentrate level as one factor and the type of silage as another. In the case of silages, tests were made on different additives (Ettala et al. 1975 a and b) in trials 1 and 2, the level of N fertilization in trial 3 (Ettala et al. 1974), and harvesting stages in trials 4 and 5 (Ettala et al. 1978).

Preceding a trial, cows were kept on a uniform silage-containing diet for 15 or 20 days, after which they were transferred to the trial diets over a period of 5 or 10 days. Before this transfer, the cows were divided into groups as comparable as possible in respect of liveweight, daily production, milk fat percentage, stage of lactation and voluntary silage intake.

Feeding, sampling and analytical methods

Cows were fed twice a day. Daily rations contained 2 kg hay, silage *ad libitum* and barley as the only concentrate fed at four different levels in three trials and at three levels in two trials (Table 1).

The same reference level of barley supply, 400 g per kg 4 % fatcorrected milk (FCM) produced over 10 kilogram's daily yield, was included in all trials.

The energy and protein feeding standards applied, as well as analytical methods and sampling, are described in a previous paper (Ettala and Lampila, 1978).

Table 1. Feed and dry matter intakes at different levels of barley supply.

Barley supply levels in different experiments	No. of cows	Barley kg DM		Silage kg		Silage kg DM		Hay kg DM		Total kg DM	
		mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Experiments 1—2											
1. 0-level	16	—	—	$43,5^{bcde}$	4,6	$11,2^{bcde}$	1,5	1,6	0,1	$12,8^{d}$	1,5
2. 133 g/kg 4 % milk over 10 kg	15	0,6	0,4	$44,7^{ce}$	4,2	$11,5^{ce}$	1,5	1,6	0,0	$13,7^{e}$	1,7
3. 267 g/kg » » » » »	16	1,6	0,7	$41,9^{abde}$	4,5	$10,8^{abde}$	1,8	1,6	0,0	$14,0^{e}$	1,8
4. 400 g/kg » » » » »	15	2,1	1,0	$40,7^{ad}$	5,2	$10,5^{ad}$	1,6	1,6	0,1	$14,2^{e}$	1,7
Experiment 3											
1. 267 g/kg 4 % milk over 10 kg	12	0,8	0,3	$40,1^{f}$	4,0	$10,2^{f}$	1,2	1,5	0,1	$12,4^{ad}$	1,2
2. 400 g/kg » » » » »	12	1,5	1,4	$39,2^{ef}$	4,5	$9,9^{ef}$	1,2	1,4	0,1	$12,9^{ade}$	2,0
3. 267 g/kg » » » 5 kg	12	2,3	0,6	$37,1^{de}$	2,5	$9,4^{de}$	0,7	1,4	0,2	$13,1^{abde}$	1,0
4. 400 g/kg » » » » »	12	3,4	1,3	$34,7^{d}$	4,2	$8,8^{d}$	1,1	1,5	0,1	$13,7^{be}$	1,7
Experiments 4—5											
1. 400 g/kg 4 % milk over 10 kg	24	3,3	1,0	$43,8^{e}$	5,8	$10,3^{e}$	1,2	1,5	0,2	$15,0^{a}$	1,7
2. 400 g/kg » » » 7,5 kg	24	4,1	0,9	$40,8^{de}$	5,0	$9,6^{de}$	1,0	1,5	0,2	$15,1^{e}$	1,3
3. 400 g/kg » » » 5 kg	24	5,0	1,2	$39,9^{d}$	5,4	$9,3^{d}$	1,0	1,5	0,2	$15,8^{a}$	1,8

s.d. = standard deviation.

The significance of differences was tested by the least squares analysis of variance, and the differences in the means were tested by Tukey's test. Values in the same column and group of experiments without a common superscript letter differ significantly; a—c : $P < 0,05$, d—f : $P < 0,01$.

Statistical analysis

The least squares analysis of variance was used (HARVEY 1966). The effect of among-cow differences was eliminated by using the results of the preliminary periods as linear regression variables.

The results were analysed twice; the interaction between the different factors was included in the first run, and then, if the interactions were not significant, a second analysis was performed in which it was excluded. The results of each trial were first analysed separately and then the replicate trials were combined (trials 1 and 2, and 4 and 5), and the year of a trial was used as an additional factor.

RESULTS AND DISCUSSION

Feed consumption

Data on feed intake at the different concentrate feeding levels are given in Table 1. The average barley intake varied from 0 to 5 kg dry matter (DM). At the reference level (400 g/kg 4 % milk over 10 kg) the daily intakes of silage DM in the different trials were 10,5 kg, 9,9 kg and 10,3 kg per cow, respectively. When the barley supply was increased, silage consumption decreased (exception: trials 1 and 2, level 2). In all the trials, silage intake differed significantly between the highest and the lowest concentrate levels. There were also significant differences between other levels in the three first trials. The intake of hay was not affected by the barley supply.

The total DM intake rose with the barley supply level. Differences in the total DM intake in trials 1, 2 and 3 were significant. At the 0 level, the intake of DM was significantly smaller than at all the other levels in the same trial. In trial 3, the DM intake was smaller at two lowest concentrate levels than at the highest level.

The effects of the increase in the barley intake were calculated from the difference between the lowest and highest concentrate levels in each trial. The results show that each additional kilogram of barley DM decreased silage intake by 1,9 kg (490 g DM) per cow per day, and increased total DM intake by 550 g. Concerning these results, it may be noted that in a larger eliminated material, including the present trials, an additional kilogram of barley DM was found to lower silage intake by 2,7 kg and silage DM intake by 640 g/cow per day, and to raise the total DM intake by 360 g (ETTALA and LAMPILA 1978).

In many other studies, the decrease in roughage intake has been found to vary between 0,2 and 1,0 kg DM per additional kilogram of concentrate DM (CAMPLING and MURDOCH 1966, CASTLE and WATSON 1961, 1975, EKERN 1972 b, FOOT and LINE 1966, FORRES and IRVIN 1970, HOLMES et al. 1957, 1960, MATHER et al. 1960, MURDOCH and HODGSON 1967, WILKINSON 1969). MÄKELÄ (1956) came to the conclusion that each kilogram of concentrate DM consumed decreased the intake of roughage DM by 0,5 kg. Corresponding decrease in roughage intake in EKERN's (1972 b) experiments was greater in earlier than in later stages of lactation (0,9 kg vs. 0,3—0,5 kg DM/kg DM). HOLMES et al. (1957) found that the increase in total DM intake per kilogram concentrate fed was greater in cows with a high production level than in animals at a low stage of production. According to the study of WIKTORSSON and BENGTSSON (1973) the DM intake of cows with high milk production was greatest when the concentrate constituted 45—50 % of DM intake, and the fibre content of the diets was around 16 % of DM.

Composition of the diets and nutrient supply

Composition, estimated net energy values and DCP contents of the feeds are shown in Table 2, and composition of the diets in Table 3.

Table 2. Composition and estimated net energy and DCP contents of feeds.

Feeds	DM %	% in DM						per f.u.		
		Ash	Crude fat	Crude fibre	N-free extract	Crude protein	DCP	kg	DM kg	DCP g
Silages										
Expt. 1 (1970—71)	23,2	8,7	6,0	30,5	38,2	16,6	12,1	5,3	1,21	146
Expt. 2 (1971—72)[1]	27,7	11,6	5,1	22,6	41,3	19,5	11,7	5,6	1,53	178
Expt. 3 (1972—73)	25,2	10,3	5,4	28,1	39,3	16,9	11,9	5,5	1,38	164
Expt. 4 (1973—74)	24,1	11,9	5,4	28,2	36,1	18,4	13,4	6,1	1,44	193
Expt. 5 (1974—75)	23,4	14,3	5,6	26,0	35,5	18,5	12,7	6,5	1,52	193
Hay										
Expt. 1	77,5	7,8	2,6	32,0	47,2	10,3	5,7	2,4	1,89	107
Expt. 2	81,0	6,4	2,3	30,3	52,0	9,0	6,4	1,8	1,49	95
Expt. 3	79,8	8,3	2,1	35,3	43,9	10,4	7,3	2,2	1,77	129
Expt. 4	81,7	6,7	1,8	34,1	44,8	12,6	8,8	2,1	1,69	149
Expt. 5	81,9	7,8	2,0	35,1	43,7	11,3	8,0	2,1	1,75	139
Barley										
Expt. 1	86,9	3,1	2,2	5,2	75,6	13,9	10,1	1,0	0,88	89
Expt. 2	87,7	2,7	2,1	4,5	77,5	13,1	9,6	1,0	0,87	84
Expt. 3	87,3	2,7	2,0	5,0	76,1	14,2	10,4	1,0	0,85	89
Expt. 4	86,6	4,7	1,9	6,5	70,5	16,5	11,8	1,1	0,92	109
Expt. 5	85,4	4,4	1,7	7,1	68,4	18,4	14,3	1,1	0,93	133

1) clover 33 %

Table 3. Mean roughage—to—concentrate ratio and composition of diets.

Experiments and barley supply levels	Roughage-to-contentrate ratio			% in DM		
	DM	f.u.	DCP	Crude protein	Crude fibre	N-free extract
Experiments 1—2						
1. 0-level	100: 0	100: 0	100: 0	16,8	26,5	42,2
2. 133 g/kg 4 % milk over 10 kg	96: 4	94: 6	96: 4	16,8	25,4	43,6
3. 267 g/kg » » » » »	88:12	83:17	89:11	16,4	24,0	46,1
3. 400 g/kg » » » » »	85:15	78:22	86:14	16,3	23,1	47,4
Experiment 3						
1. 267 g/kg 4 % milk over 10 kg	94: 6	90:10	94: 6	15,9	27,6	42,2
2. 400 g/kg » » » » »	89:11	83:17	90:10	15,8	26,4	44,0
3. 267 g/kg » » » 5 kg	83:17	74:26	84:16	15,7	25,0	46,2
4. 400 g/kg » » » » »	75:25	65:35	76:24	15,4	23,2	49,0
Experiments 4—5						
1. 400 g/kg 4 % milk over 10 kg	79:21	68:32	81:19	17,3	22,7	45,0
2. 400 g/kg » » » 7,5 kg	73:27	61:39	76:24	17,1	21,4	47,2
3. 400 g/kg » » » 5 kg	69:31	56:44	72:28	17,0	20,4	49,0

The average contribution of silage in the daily rations was: 72 % of the DM intake, 67 % of the estimated net energy and 78 % of the DCP supply. The corresponding contributions of hay were 11, 8 and 7 %, and those of barley 17, 25 and 15 %, respectively. The roughage-to-concentrate ratio changed with the concentrate level (Table 3). The starting point was 100 : 0, and the lowest ratio on the net energy basis at the average production stage was 56 : 44.

The decrease in the crude protein content of the diets with increasing barley supply was rather small (0,3—0,5 % units of DM in the different trials), but the decrease in the crude fibre content was considerable (2,3—4,4 % units of DM), as was also the increase in the

Table 4. Estimated daily energy and protein intakes, and energy and protein balances.

Experiments and barley supply levels	Barley		Silage		Hay		Total		Supply-requirement	
	f.u.	DCP, g	f.u.	DCP, g	f.u.	DCP, g	f.u.	DCP, g	f.u.	DCP, g
Experiments 1—2										
1. 0-level	—	—	8,3^{bde}	1 317de	0,9^{a}	93^{e}	9,2^{ad}	1 410^{a}	—0,5^{ad}	+207^{a}
2. 133 g/kg 4 % milk over 10 kg	0,7	57	8,5^{ce}	1 360^{e}	0,9^{a}	92de	10,1^{be}	1 510^{a}	+0,3^{bde}	+297^{a}
3. 267 g/kg » » » » »	1,8	160	7,9^{abde}	1 273de	0,9^{a}	92de	10,7^{bce}	1 524^{a}	+0,1^{abde}	+186^{a}
4. 400 g/kg » » » » »	2,4	210	7,7^{ad}	1 239^{d}	0,9^{a}	91^{d}	11,1^{ce}	1 540^{a}	+0,7^{be}	+242^{a}
Experiment 3										
1. 267 g/kg 4 % milk over 10 kg	0,9	78	7,4^{f}	1 187^{ce}	0,8^{a}	109^{a}	9,1^{d}	1 374^{d}	+0,1^{d}	+268^{a}
2. 400 g/kg » » » » »	1,8	159	7,2^{ef}	1 167^{bce}	0,8^{a}	104^{a}	9,8^{de}	1 430de	+0,4^{d}	+259^{a}
3. 267 g/kg » » » 5 kg	2,7	233	6,8^{de}	1 102^{abde}	0,8^{a}	105^{a}	10,3^{e}	1 440de	+0,5^{d}	+226^{a}
4. 400 g/kg » » » » »	4,1	355	6,3^{d}	1 027^{ad}	0,8^{a}	108^{a}	11,2^{f}	1 490^{e}	+1,3^{e}	+245^{a}
Experiments 4—5										
1. 400 g/kg 4 % milk over 10 kg	3,8	346	6,9^{e}	1 377^{e}	0,9^{a}	126^{a}	11,6^{d}	1 848^{a}	—0,0^{ad}	+354^{a}
2. 400 g/kg » » » 7,5 kg	4,7	432	6,5^{de}	1 294de	0,9^{a}	128^{a}	12,1^{de}	1 854^{a}	+0,5^{bde}	+370^{c}
3. 400 g/kg » » » 5 kg	5,8	529	6,3^{d}	1 260^{d}	0,9^{a}	122^{a}	12,9^{e}	1 910^{a}	+0,9^{be}	+357^{a}

Significance of differences tested as explained in Table 1.

nitrogen-free extract (4—7 % units of DM). The average crude protein content of the diets at the highest concentrate level was 17 % and the crude fibre content 20,4 % (Table 3).

Daily energy and protein intakes per cow are shown in Table 4. Barley supplied from 0 to 5,8; silage 6,3—8,5 and hay 0,8—0,9 f.u. daily. Differences in the estimated total net energy intake were highly significant ($P < 0,01$) between the highest and lowest levels of concentrate supply. Significant differences are also to be seen between other levels, while the variation in the total intake of DCP is rather small. The intake of DCP exceeded the estimated average requirement in all trials, while that of energy satisfied the requirement at all concentrate levels except the 0 level. Energy intake exceeded the requirement at the higher levels.

Liveweights of the cows shown in Fig. 1 remained fairly constant in all groups. This indicates that the differences in the calculated energy intake between the treatments cannot be considered real. Instead, they may be useful for adjustments of the calculation system.

Roughage-to-concentrate ratio was, on average, relatively high also at the highest level of concentrate supply (59 : 31) as compared with the ratios at which the highest DM and energy intakes have most often been found. In the studies of Kesler and Spahr (1964) and of Wiktorsson and Bengtsson (1973), maximum intakes were found when concentrates contributed 45—60 % of the total DM intake. Average crude fibre content in the DM of the rations then was in the range 14—16 percent whereas it was about 20 % in the present work.

It thus appears very probable that highest possible DM intakes have not been achieved in the present work although the highest shares of concentrate approached the range mentioned above. Excessive supplies of DCP and relatively small changes in its total intake indicate that a further increase in the concentrate supply might have been possible without serious effects on the protein supply at the highest levels of production.

Milk production and liveweight of the cows

From the results given in Table 5 and Fig. 1 it may be noticed at first that the average daily milk production at the no-concentrate level was 14,8 kg, differing significantly ($P < 0,05$—$P < 0,01$) from the production at other levels except level 2 (133 g/kg 4 % milk over 10 kg). During the first month of the trial period, milk production at the no-concentrate level fell rapidly to a daily average of 14 kg. The weight

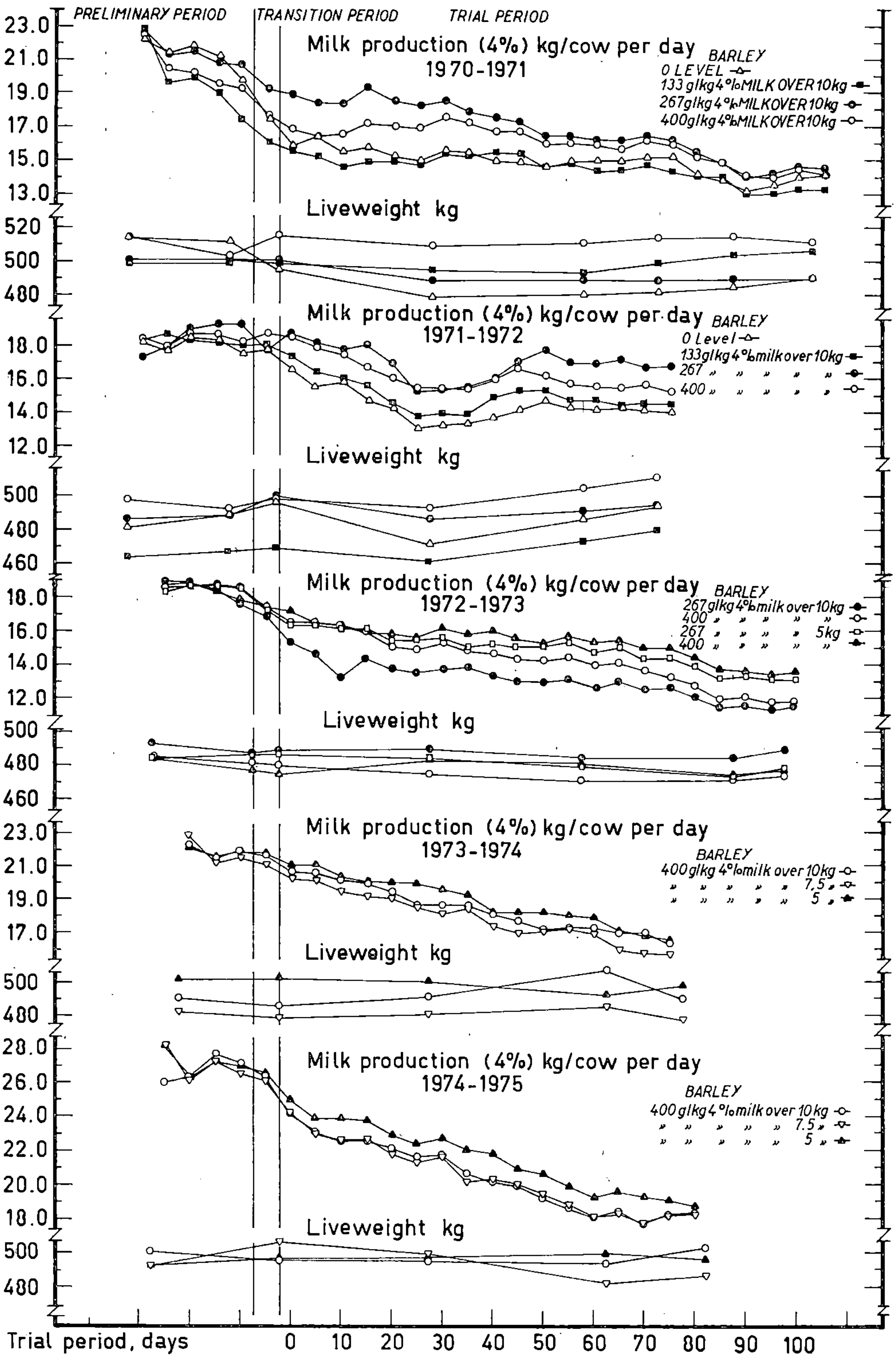

Fig. 1. Changes in milk yield and liveweights at different concentrate feeding levels in trials at Jokioinen 1970—1975.

Table 5. Daily milk production, milk composition and liveweight changes during the trial periods.

Experiments and barley supply levels	Daily milk yield				Milk composition, %						Liveweight, kg		
	kg		kg 4 % FCM		Fat		Protein		Lactose				Change
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	
Experiments 1—2													
1. 0-level	14,8[ad]	2,2	14,6[ad]	2,4	3,89[a]	0,20	3,02[a]	0,25	4,79[ad]	0,23	482	35	+ 1
2. 133 g/kg 4 % milk over 10 kg	14,7[abde]	3,4	14,8[abde]	3,3	4,05[a]	0,24	3,11[a]	0,29	4,85[ade]	0,14	482	44	+10
3. 267 g/kg » » » » »	16,8[ce]	2,8	16,8[ce]	2,8	4,03[a]	0,36	3,09[a]	0,39	4,87[abde]	0,22	491	56	—10
4. 400 g/kg » » » » »	16,1[bcde]	3,0	16,1[bcde]	2,9	4,00[a]	0,32	3,24[a]	0,32	4,91[be]	0,21	506	63	+ 6
Experiment 3													
1. 267 g/kg 4 % milk over 10 kg	12,7[a]	1,4	13,0[ad]	1,6	4,13[a]	0,23	3,23[a]	0,27	4,62[a]	0,23	486	59	+ 3
2. 400 g/kg » » » » »	13,8[ab]	3,7	14,1[abde]	4,1	4,14[a]	0,31	3,23[a]	0,32	4,59[a]	0,24	473	43	— 6
3. 267 g/kg » » » 5 kg	14,2[ab]	2,8	14,8[bde]	2,8	4,33[a]	0,34	3,25[a]	0,23	4,71[a]	0,22	480	35	— 8
4. 400 g/kg » » » » »	14,8[b]	3,5	15,3[be]	3,6	4,31[a]	0,27	3,31[a]	0,23	4,77[a]	0,25	479	34	+ 2
Experiments 4—5													
1. 400 g/kg 5 % milk over 10 kg	18,5[a]	2,5	19,4[a]	2,9	4,39[a]	0,33	3,40[a]	0,20	4,95[a]	0,15	490	38	+ 3
2. 400 g/kg » » » 7,5 kg	18,4[a]	2,8	19,3[a]	2,5	4,39[a]	0,32	3,50[a]	0,24	4,98[ab]	0,14	487	55	+ 1
3. 400 g/kg » » » 5 kg	19,7[a]	3,0	20,4[a]	2,9	4,32[a]	0,37	3,45[a]	0,27	5,00[b]	0,13	498	58	+ 7

Significance of differences tested as explained in Table 1.

of the cows also fell in this group. The average estimated energy deficit was then about 1,5 f.u. per cow per day. In the later part of the trial period, when the energy supply equalled or exceeded requirement, production became fairly constant, and there was a slight increase in liveweight.

The response of the cows to the low levels of barley supply appears very much the same in the case of milk yield in all trials. Limited energy intake resulted in a rapid decrease of production until a certain level had been attained (Fig. 1). This level varies in different cases in the range of about 14 to 18 kg. Depending on the levels of barley supply, the effects may or may not have resulted in statistically significant differences between the average yields, as shown in Table 5. Changes of liveweight have so far been so irregular and small that the response to the variations in energy intake seem to have been limited to the milk yield only.

Calculated from the differences in the milk yield between the highest and lowest concentrate feeding levels in each trial, the average increase in 4 % milk production was 730 g per cow per day for each additional kilogram of barley DM. The corresponding effect in other studies has varied from ca. 0,5 to 1,7 kg per cow per day for each kg of concentrate DM (Broster et al. 1958, 1969, Broster and Tuck 1967, Burt 1957, Castle and Watson 1961, Holmes et al. 1957, 1960, Mather et al. 1960). Broster et al. (1958, 1969) reported that an increase in concentrate supply had a greater effect at an earlier than at a later stage of lactation. Holmes et al. (1957) and Mather et al. (1960) found that the effect was stronger in cows with high milk production than in cows with low production.

Depending on the reference level, an increase in the concentrate supply has either resulted in an elevated milk yield (Bishop et al. 1963, Castle et al. 1958, 1959, Castle and Watson 1975, Huber and Boman 1966, Murdoch and Hodgson 1967), has had no effect, or has even decreased the production, (Elliot and Loosli 1959, Ekern 1972 a, Holmes et al. 1956, Hoogendoorn and Grieve 1970, Kesler and Spahr 1964, Nelson et al. 1968, Nordfeldt and Ruudvere 1963, Nordfeldt and Claesson 1964).

In the study of Nordfeldt (1966), best milk yields were obtained when the concentrate made up 60 % of the feed units in rations containing either hay or silage as the only roughage. When both were included (1 : 1), the optimal roughage-to-concentrate ratio (f.u./f.u.) was 55 : 45. This is about the same as the mean roughage-to-concentrate ratio, 56 : 44, that gave the best results in the present work.

Milk composition

The effect of the level of concentrate feeding on milk composition is shown in Table 5. With increasing barley supply a rising trend becomes evident in the contents of milk fat, protein and lactose, but significant differences are to be seen only in the lactose contents in trials 1—2 and 4—5. The protein content in trial 4 was significantly affected by the interaction of the concentrate level and the stage at which the silage was harvested, and the lactose content in trial 3 was significantly affected by the interaction of the concentrate level and the level of nitrogen fertilizer (cf.p. 177). When the effect of feeding on milk composition was examined in a larger material, with some of the present trials included (ETTALA 1976), an increase in the barley supply was found to cause a highly significant increase in the protein and fat contents of the milk.

An increase in concentrate supply has also raised the protein or solids-not-fat content of milk in many other studies. The fat content has not been strongly affected, or has even decreased at high concentrate levels (BISHOP et al. 1963, BROSTER et al. 1958, 1959, BROSTER and TUCK 1967, BURT 1957, CASTLE et al. 1958, 1959, CASTLE and WATSON 1961, 1975, HOLMES et al. 1956, 1957, 1960, HUBER and BOMAN 1966, KESLER and SPAHR 1964, MURDOCK and HODGSON 1967, NELSON et al. 1968, NORDFELDT and RUUDVERE 1963). In general, the effect of the concentrate feeding level on the lactose content has been small (CASTLE and WATSON 1975, ETTALA 1976, HOLMES et al. 1957, 1960, HUBER and BOMAN 1966, NORDFELDT and RUUDVERE 1963).

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SELOSTUS

Erilaisia väkirehutasoja nurmisäilörehuvaltaisessa lypsykarjaruokinnassa

Elsi Ettala, Martti Lampila ja heikki Rissanen

Maatalouden tutkimuskeskus

Vuosina 1970—75 tehtiin Jokioisten kartanon Lintupajun tilalla viisi ruokintakoetta, joissa oli yhteensä 182 ay-lehmää. Lehmät saivat vapaasti säilörehua, 2 kg päivässä heinää ja erilaisten annostustasojen mukaan ohraa. Ohra-annokset olivat 0, 1/3, 2/3 tai 3/3 siitä lasketusta ry-määrästä (0, 133, 267 tai 400 g/kg 4 % maitoa), jonka lehmät tarvitsivat tuottaakseen maitomäärän, joka ylitti 10, 7,5 tai 5 kg 4-prosenttiseksi muunnettua maitoa päivässä. Lehmien keskimäärin syömästä kuiva-aineesta oli 17 % ohraa, 72 % säilörehua ja 11 % heinää.

Ohra-annoksen lisääminen vähensi säilörehun ja lisäsi koko kuiva-aineen syöntiä. Jos tulokset lasketaan kunkin kokeen alimman ja ylimmän väkirehutason mukaan, säilörehun kuiva-aineen syönti väheni 490 g ja koko kuiva-aineen syönti lisääntyi 550 g lehmää kohti päivässä kutakin lisättyä ohran kuiva-ainekiloa kohti.

Maidontuotanto kohosi ohra-annostuksen nousun myötä. Jos laskelma tehdään kunkin kokeen alimman ja ylimmän väkirehutason mukaan, nousu oli 730 g 4 % maitoa lehmää kohti päivässä kutakin lisättyä ohran kuiva-ainekiloa kohti. Maitosokeripitoisuus kohosi merkitsevästi ohra-annoksen lisääntyessä. Elopainon muutokset olivat pieniä ja säännöttömiä.

ANNALES AGRICULTURAE FENNIAE, VOL. 17: 185—191 (1978)
Seria AGRICULTURA N. 59 — Sarja PELTOVILJELY n:o 59

THE TEMPERATURE SUM REQUIREMENTS OF BARLEY VARIETIES IN FINLAND

ULLA LALLUKKA, OLLI RANTANEN and JAAKKO MUKULA

LALLUKKA, U., RANTANEN, O. and MUKULA, J. 1978. **The temperature sum requirements of barley varieties in Finland.** Ann. Agric. Fenn. 17: 185—191. (Agric. Res. Centre, Inst. Plant. Husb., SF-01300 Vantaa 30, Finland).

The temperature sums computed in different ways (above 0 °C, +2 °C, +5 °C) have proved more effective in depicting the length of the growing period for barley than the growing period computed in days. However, it was observed that the average temperature of the growing period does often have a significant effect on the temperature sum needed by a variety. When an effective temperature sum (above +5 °C) was used, the temperature sum requirement of the barley varieties increased along with an increase in the average temperature of the growing period. This is probably why the effective temperature sum requirements of barley varieties vary in different parts of Finland. On the other hand, the average temperature of the growing period did not have a significant effect on the magnitude of the sum of growing period temperatures above +2 °C. Computed in this way, the temperature sum would appear on average to be the best estimate of the growing period for barley under Finnish conditions.

Index words: temperature sum, barley growing period.

INTRODUCTION

The growing season is considered to be that period during which the average daily temperature is above +5 °C (NUTTONSON 1957). The Finnish Meteorological Institute reports on the progress of the growing season by means of the so-called effective temperature sum. Computed on this basis, the temperature sum in southern Finland during the whole growing season amounts to 1 200 K on average. The figure for the northern limit of the barley cultivation area is 900 K. However, some of this temperature sum is lost, for due to excess soil moisture, sowing cannot be carried out until 1—2 weeks of the growing season have already elapsed. Moreover, some annual fluctuations in the temperature sum exist.

The average temperature sum requirements of Finnish varieties of barley vary between 800 and 1 000 K. Since it is known that the varieties with the highest temperature sum requirements produce the highest yields, it is tempting to make optimum use of the available temperature sum to obtain a greater yield. For this reason the varieties which barely have time to ripen in the areas in question are usually preferred. Thus, in order to minimize the risk involved in farming, it is important to have the most exact data possible on the temperature sums required by the different varieties for ripening. In connection with a study concerning the risks to cultivated crops (Mukula et al, 1977) under Finnish conditions, the temperature sum requirements of Finnish barley varieties were determined and the factors affecting them were studied.

MATERIAL

The temperature sum requirements of the barley varieties were studied using phenological and weather observations from barley variety experiments performed at 8 experimental stations of the Agricultural Research Centre. The computations included a total of 245 observations made on Otra, Pomo and Karri varieties in 1968—77. The interdependence between the effective temperature sum of the growing period and the average temperature at the time in question were also determined for Tammi barley on the basis of variety experiments performed in 1936—62.

The significance of the results is expressed as follows: °P < 0,10, * P < ** 0,05, *** P < 0,01, 0 < 0,001.

RESULTS AND DISCUSSION

It was discovered that there were differences between experimental stations with respect to the effective temperature sums required for ripening of the same variety. The average temperature during the growing period of the variety was found to affect the variation in the temperature sum required by the variety (Fig. 1). There was a positive correlation between the average tem-

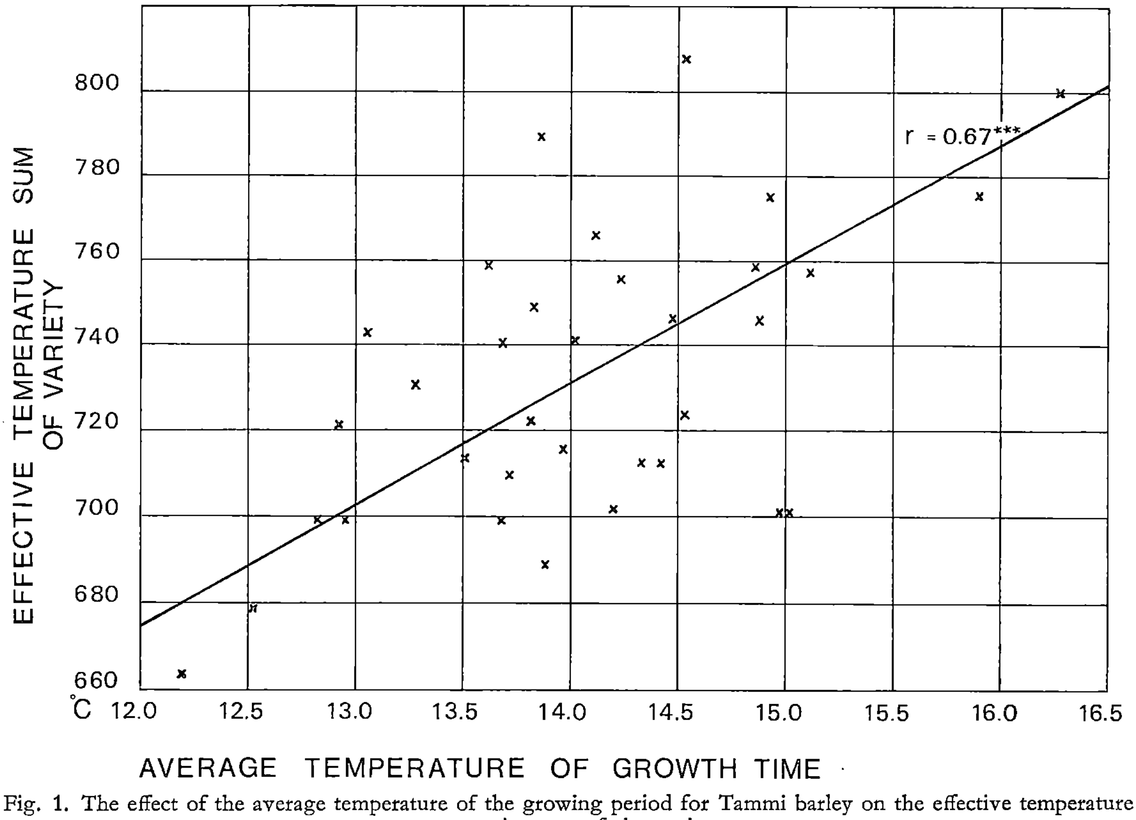

Fig. 1. The effect of the average temperature of the growing period for Tammi barley on the effective temperature sum requirement of the variety.

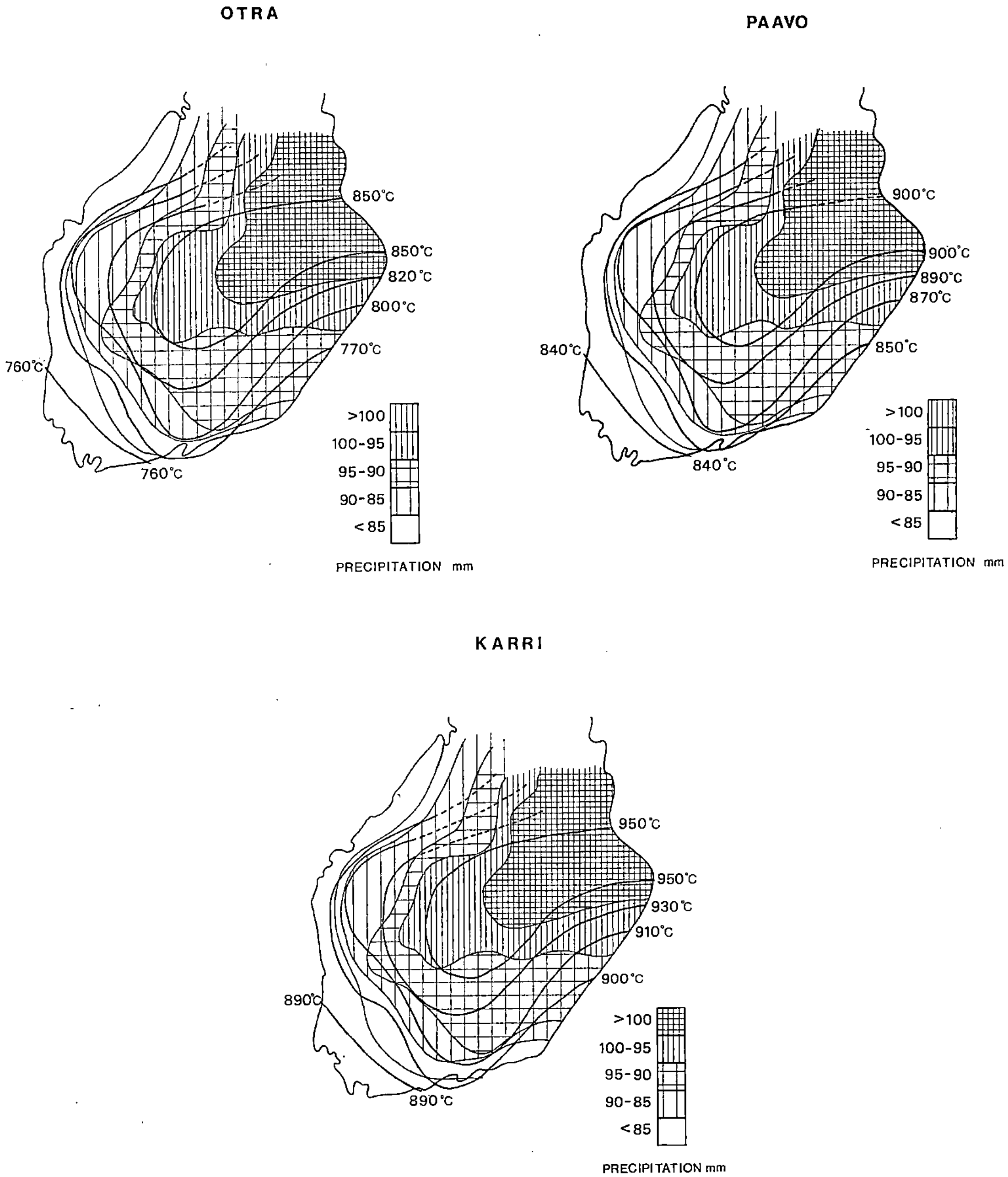

Fig. 2. The average, effective temperature sum requirements for Otra, Paavo and Karri varieties in various parts of Finland. (The shaded area represents the regional distribution of precipitation in May—June).

perature and the effective temperature sum. This correlation obviously affected differences in the temperature sum needed by the variety both annually and regionally.

Figure 2 shows that the effective temperature sums needed for the ripening of barley are highest in the central parts of the country. The actual average temperature of the growing period

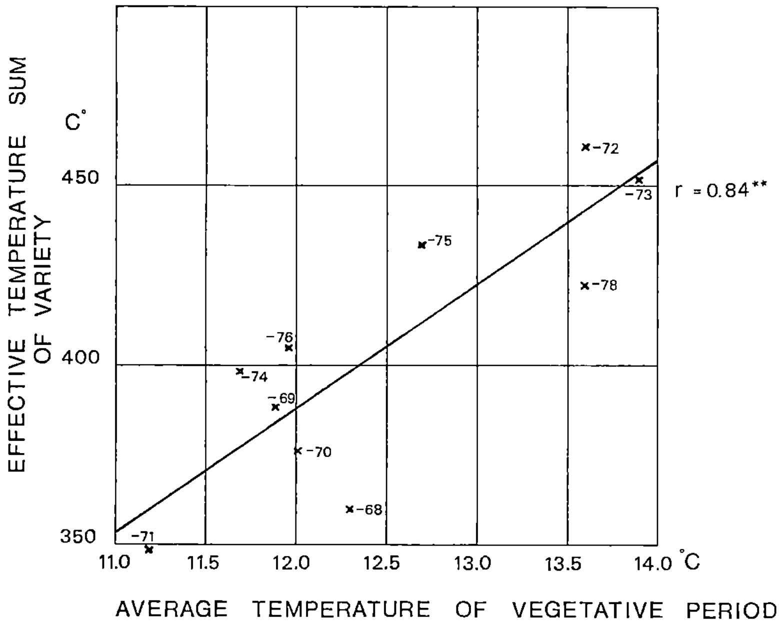

Fig. 3. The effect of the average temperature of the vegetative phase of Otra barley on the effective temperature sum requirement during the same period.

for barley in the central parts of the country is relatively high. This is because excess spring moisture makes it necessary to sow barley later in this area than in southern Finland. The high temperature sum requirement for barley varieties in central Finland may also be caused by moisture conditions which are more favourable than those in southern Finland during the rest of the growing season. In northern Finland the entire growing season is so much cooler, that the average temperature of the growing period for barley is lower there, regardless of the late sowing.

The interdependence of the average temperature and the effective temperature sum during growing time was also studied separately for the various phases in the development of barley. The effective temperature sum needed at the beginning (sowing-heading) proved highly dependent on the average temperature at the time in question (Fig. 3). During the reproductive phase (heading—yellow ripeness), however, no significant correlation was found between the average temperature and the effective temperature sum requirement for the period in question. Factors other than temperature seemed to have a greater effect on that phase. Valmari (1972) has shown that the total hours of sunshine are important, particularly while the grains are ripening. In this study, too, the precipitation and temperature conditions in early summer had a great effect on the magnitude of the temperature sum required for the formation of the barley grain and for ripening. This is understandable, for these factors have a pronounced effect on shooting and on the number of grains. This means that the final sequence of development is shortened, and the temperature sum needed for it is smaller. Drought reduces the necessary temperature sum, particularly in the coastal area of southern and southwestern Finland.

According to Swedish studies (Åkerberg & Haider 1976), a long day and low average temperature reduces the number of grains in northern areas and makes the period during which the grains swell shorter than under short day conditions. This is apparently the case in Finland, too. In other words, the difference in the length of the day between southern and northern Finland reduces the temperature sum requirements in the fringe areas of barley cultivation.

The aim in using the temperature sum instead of the number of growth days to depict the growing period of the variety, is to arrive at a constant estimate for each variety. However, this study indicates that the sum of temperatures above +5 °C is smaller for barley varieties during cool summers than during warm summers. The use of this, so-called, effective temperature sum, to depict the growing season is based on the assumption that cereals are only able to use temperatures above +5 °C for their growth and development. However, the varieties bred for cultivation under Finland's cool growing conditions may perhaps be able to make use of even lower temperatures. Thus, deducting five degrees from the mean daily temperature may then result in too small a temperature sum in cool summers, when the number of growing days is large. It may also be possible that cereals cannot make full use of the highest temperatures during warm growing seasons. In such cases their inclusion in the temperature sum required by the variety would result in a higher value than the temperature sum really needed by the variety.

The above observations suggested an attempt to find such a temperature sum that was least variable and also independent of the growing period temperature.

At first it was observed that when the growing period was measured with the temperature sum, the variation was clearly smaller than when the length of the growing period was expressed in growing days (Table 1). The differences between the variation coefficients of the temperature sums computed in different ways were minor.

In studying the correlation between the temperature sums and the average temperatures of the growing period, it was observed that the temperature sum exceeding +2 °C was almost independent of the average temperature of the growing period of the barley varieties (Table 2, Fig. 4).

Table 1. The variation coefficients of the growing days and the various temperature sums for Otra, Paavo and Karri varieties and for the material as a whole.

Growing time	Variation coefficient			
	Otra	Paavo	Karri	All the varieties
Growing days	11,2	11,7	10,2	12,8
Temperature sum above 0	7,0	5,9	4,1	8,4
Temperature sum above +2	6,8	5,6	4,2	8,2
Temperature sum above +5	7,6	5,8	5,2	8,7

Table 2. Correlation coefficients between the average temperature of the barleys' growing period and the temperature sums computed in different ways — by variety and in the entire material.

Temperature sum	Correlation coefficient			
	Otra	Paavo	Karri	All the varieties
above 0	—0,14	—0,24*	—0,20°	—0,12°
above +2 ..	0,1	—0,01	0,1	0,01
above +5 ..	0,33**	0,42**	0,58**	0,35**

The site of the experimental station, however, appeared to have an effect on which temperature sum was most exact. In studying the different temperature sums at different experimental stations, the number of observations remained rather small. However, the sowing time at the experimental station did appear to affect the suitability of temperature sums. If the average temperature during the growing period rose due to the delayed sowing, the effective temperature sum was a more accurate estimate of growing time than temperature sums above 0 °C or, 2 °C, despite the fact that the value was somewhat dependent on the average temperature of the growing period.

The following assumptions can be made on the basis of this material: if the barley was sown rather early, in which case the temperature during shooting and the initial phase of growth is relatively low, the barley is able to make use of nearly all the available warmth. In this case the temperature sum, which also includes either all (above 0 °C) or nearly all the temperatures (above +2 °C), is very accurate in depicting

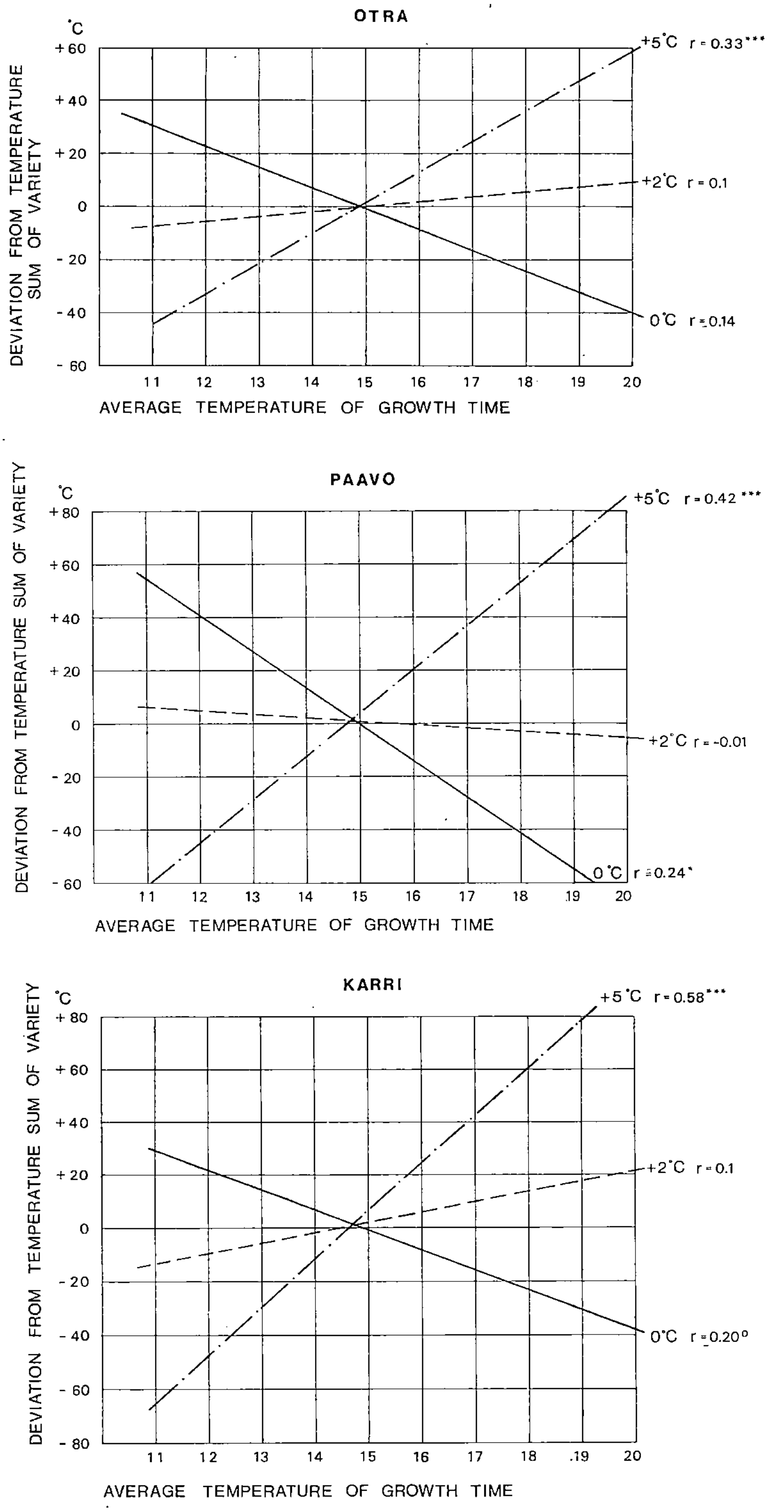

Fig. 4. The effect of the average temperature of the growing period of Otra, Paavo and Karri varieties on the temperature sum requirements computed in different ways. The temperature sums in the figure are deviations from the average of the temperature sum in question.

growing period of barley varieties under Finnish conditions. However, when sowing is delayed, the average temperature of the above-mentioned phase may be quite high, and as a result, some of the warmth is apparently lost. Therefore, in such conditions, the temperature sum calculated by deducting +5 °C from the daily mean temperature may on average provide a more accurate indication of the temperature sum needed by the barley than a sum of the temperatures above +2 or 0 degrees.

According to this material it would seem, that under Finnish conditions, the sum of temperatures exceeding +2 °C is the most accurate estimate of the development of barley varieties. The two other temperature sums are also accurate when measuring the length of the growing period. However, it is useful to take into account the correlation between the temperature sum and the average temperature of the corresponding period when using them to depict the growing period.

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SELOSTUS

Ohralajikkeiden lämpötilasummavaatimukset Suomessa

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Maatalouden tutkimuskeskus

Maatalouden tutkimuskeskuksen ohran lajikekoeaineistosta vuosilta 1967—1977 tutkittiin Otra-, Paavo- ja Karri-ohrien kasvuajan lämpötilasummien soveltuvuutta kasvuajan pituuden kuvaajaksi.

Kasvuajan tehoisan lämpötilasumman ja ajanjakson keskilämpötilan vuorovaikutusta selvitettiin myös Tammi-ohralla vuosien 1936—1962 lajikekokeiden perusteella.

Lämpötilakertymien, jotka oli laskettu ohran kasvuajan 0 °C, +2 °C tai +5 °C ylittävien päivittäisten keskilämpötilojen summana todettiin paremmin kuvaavan kasvuajan kestoa kuin päivissä lasketun kasvuajan. Kuitenkin kasvuajan keskilämpötilan havaittiin usein merkitsevästi vaikuttavan tarvittavan lämpötilasumman suuruuteen. Tehoisaa lämpötilasummaa käytettäessä ohralajikkeiden lämpötilasummavaatimus oli sitä suurempi mitä korkeampi oli sen kasvuajan keskilämpötila. Todennäköisesti tästä johtuen ohralajikkeiden tehoisan lämpötilasumman vaatimukset olivat erilaiset eri osissa Suomea. Kasvuajan +2 °C ylittävien lämpötilojen summan suuruuteen ei kasvuajan keskilämpötila sensijaan merkitsevästi vaikuttanut. Näin laskettu lämpötilasumma näyttäisikin Suomen oloissa sopivan parhaiten ohran kasvuajan kuvaajaksi.

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Seria AGROGEOLOGIA ET -CHIMICA N. 89 — Sarja MAA JA LANNOITUS n:o 89

THE EFFECT OF MAGNESIUM FERTILIZING ON SPRING CEREAL AND CULTIVATED LEY YIELD AND ON SOIL NUTRIENT CONTENTS AT TWO POTASSIUM AND NITROGEN FERTILIZER LEVELS

Raili Jokinen

Jokinen, R. 1978. **The effect of magnesium fertilizing on spring cereal and cultivated ley yield and on soil nutrient contents at two potassium and nitrogen fertilizer levels.** Ann. Agric. Fenn. 17: 192—204. (Agric. Res. Centre, Inst. Agric. Chem. and Phys., SF-01300 Vantaa 30, Finland).

The effect of magnesium sulphate fertilizing at two levels of potassium (60 and 240 kg/ha K) and nitrogen (50 and 100 kg/ha N) fertilizer on spring cereal and cultivated ley yield and on the soil nutrient state was investigated. The fertilizers were applied annually in the course of a five-year test period. Plant rotation at the various test sites was as follows: a cereal the first two years, cultivated ley the third and fourth, and a cereal the fifth year. Six of the seven tests were carried out in soil with low magnesium content.

The average increase in cereal grain yield obtained with magnesium fertilizing was 68 f.u./ha (—60—+308 f.u./ha) and the corresponding increase in cultivated ley yield was 65 f.u./ha (—293—+608 f.u./ha). The increase in yield produced by magnesium fertilizing was not significantly dependent on the nutrient state of the soil.

An increase in nitrogen fertilizing resulted in a significant increase in yields at the different test sites almost every year. The increase in yield obtained with magnesium fertilizing was not dependent on the quantity of fertilizer nitrogen, because even the larger amount of nitrogen was relatively small. The change in the magnesium content of the soil during the test period was not dependent on the amount of nitrogen fertilizing. The potassium content of the soil appeared to decline as the nitrogen was increased.

A fourfold increase in the amount of potassium caused a reduction in the cereal grain yield and in the ley crop yield. In some cases ley crops needed the larger amount of nitrogen together with magnesium fertilizing in order to offset the negative effect of the larger amount of potassium fertilizing on the yield. With the smaller amount of potassium the potassium content of the soil declined during the five-year period. Nevertheless, the highest yields were obtained with this amount of potassium. The larger amount of potassium doubled the exchangeable potassium content of the soil in comparison with the smaller amount of potassium at a few test sites.

The annual application of magnesium fertilizer raised the magnesium level of the plough layer (0—20 cm) at all the test sites. At the end of the test the change in the magnesium content (Mg_1—Mg_0) by the magnesium fertilizing was 60,4 mg/l (38—80 mg/l Mg) on average. Without magnesium fertilizing the magnesium content declined by 16,7 mg/l (13—21 mg/l) on average during the five-year period. The magnesium fertilizing increased the magnesium content of the soil below the plough layer (20—40 cm) only at test sites where the plough layer contained little organic matter. The increase was 11,4 mg/l (3—29 mg/l) on average.

Index words: magnesium, potassium and nitrogen fertilizing, cereal and cultivated ley yield, magnesium and potassium content of the soil.

INTRODUCTION

The increases in yield produced by magnesium fertilizing were minor in the field tests. The yield of cultivated leys increased with magnesium fertilizing only when the magnesium content of the soil was low (BAERUG 1977). Moreover, a condition for an increase in yield with magnesium fertilizing in the pot tests was a very low magnesium content in the substrate (JOKINEN 1977 a).

The yield of cultivated grasses particular can be raised effectively (HIIVOLA et al. 1974) by increasing the amount of nitrogen fertilizing. However, the depletion of the potassium and magnesium in the soil is intensified (BAERUG 1977), and as a result, the need for potassium and magnesium fertilizing increases. In some tests carried out in Finland it was not possible to determine the greater need for magnesium fertilizing caused by increased application of nitrogen fertilizing, because the ammonium-nitrate limestone used as fertilizer contained 3,0 % magnesium (MÄNTYLAHTI and MARJANEN 1971, SILLANPÄÄ and RINNE 1975). In these tests the magnesium in the fertilizing was as much as 73 kg/ha/y.

Application of the larger amount of potassium fertilizer or a high potassium content of the soil prevents plants from obtaining magnesium (SCHARRER and MENGEL 1958, JOKINEN 1977 b). Thus it can be assumed that an increase in both the nitrogen and the potassium fertilizing causes a need for magnesium fertilizing.

The aim of this study is to obtain data on the effect of the increase in nitrogen and potassium fertilizing on the result obtained with magnesium fertilizing when the magnesium content of the soil is low. The study focuses on two spring cereals, barley and oats, and also on biennial timothy or clover-timothy ley. The effect of fertilizers on the soil nutrient state is also monitored.

MATERIAL AND METHODS

The material was obtained from seven field tests carried out in southern and central Finland. The tests were carried out at six experimental stations in soil with a low (below 100 mg/l) magnesium content (Table 1).

The acidity of Finnish farmland and the low magnesium content are linked so closely together that it was difficult to find test sites suitable for studying the latter alone. All but one of the soils in this field material require liming. The calcium content of the soil was low at two test sites (tests 4 and 5). The potassium content was at least fair at all test sites.

During the five-year test period a spring cereal, either barley or oats, was grown in the tests during the first two years and again in the last year. Clover-timothy or timothy alone were grown during the third and fourth years. De-

Table 1. Location of field tests, soil type, soil acidity and nutrient contents.

Test n:o	Location	Soil 0—20 cm/20—40 cm	Org. C %	pH_{H_2O}	Acid ammonium acetate extractable, mg/l			
					P	K	Ca	Mg
1.	South-West Finland Exp. Sta.	Finer finesand/Finesand	1,7	5,6	5,0	124	1 180	100
2.	Satakunta Exp. Sta.	Mould/Silt	10,2	5,2	7,5	80	1 990	55
3.	South Savo Exp. Sta.	Finesand/Finesand	3,5	6,2	10,0	275	1 290	54
4.	South Pohjanmaa Exp. Sta.	Finer finesand/Finer finesand	4,7	4,8	8,2	130	480	43
5.	Central Pohjanmaa Exp. Sta. ..	Finer finesand/Finer finesand	2,4	5,2	4,7	111	370	50
6.	Karjala Exp. Sta.	Ligno Carex peat/Ligno Carex peat	17,3	4,9	8,0	143	1 780	77
7.	Karjala Exp. Sta.	Finesand/Finesand	3,9	5,6	6,9	128	1 170	26

parting from the recommendation, ley was grown in test 2 during the last year and cereals in test 6 during all five years.

The fertilizers applied annually to all plants were the same and the quantities were as follows:

N_1	= 50	kg/ha	N, nitro-chalk (15,5 % N)
N_2	= 100	»	» »
K_1	= 60	»	K, potassium chloride (50 % K)
K_4	= 240	»	» »
Mg_1	= 57	»	Mg, magnesium sulphate (19% Mg)

Furthermore, 26 kg/ha P in the form of superphoshate was also applied to the entire test area. Aftermath was not fertilized separately.

The potassium fertilizers used in the tests based on the split-plot method were whole-unit, with the nitrogen and magnesium fertilizers as sub-units of equal value. Both amounts of nitrogen were applied either without magnesium or with magnesium fertilizing. Thus there was a total of eight different treatments in the tests with four replications.

Only the grain yield of the cereals was weighed. The grass was cut twice, the first yield for dry hay as the timothy began to bloom and the second in the autumn. Hay accounted for an average of 70 % of the total ley yield in the first year ley and 80 % in the second year ley, for no fertilizer was applied to the aftermath. The main ley plant was timothy, and there was an admixture containing small amounts of red clover (less than 10 %) in only two tests (1 and 3).

Since both cereals and ley grew in the tests, the yields obtained from a hectare were given in feed units (f.u.). The following factors were used in converting dry matter yields to feed units:

barley	1,17 f.u./kg
oats	0,98 »
hay	0,52 »
aftermath	0,70 »

Soil samples of the plough layer in each plot were taken from the experiments in the spring, before fertilizer was applied. In the last year the soil samples were taken in the autumn, after the harvest, from both the plough layer (0—20 cm) and from the subsoil (20—40 cm). The potassium, calcium and magnesium extractable in acid (pH 4,65) ammonium acetate and the pH_{H_2O} (Vuorinen and Mäkitie 1955, Kurki et al. 1965) were determined for all soil samples.

The annual yield results as well as the results of the soil analyses were tested with variance analysis. The least significant difference ($LSD_{5\%}$) between the whole units (K fertilizing) and the difference between the sub-units (N and Mg treatments) at one level of potassium fertilizer (Cochran and Cox 1966) are presented separately in the tables.

RESULTS

Changes in the magnesium and potassium contents of the soil

By spring of the fourth year, the magnesium content of the soil without magnesium fertilizing had declined in all tests by 10 mg/l (57,9—48,7 mg/l Mg) on average. The change in the magnesium content was smallest in tests 1 and 2, and largest in test 3 (16 mg/l, Fig. 1). Also by the spring of the fourth year, the magnesium content of the soil in the plots which received an annual application of magnesium fertilizer had risen by 34 mg/l (57,9—91,8 mg/l) from the initial value on average. Compared with the unfertilized soil, the rise in the magnesium content was 43 mg/l on average by the spring of the fourth year.

In the autumn of the fifth test year the magnesium content of the soil without magnesium fertilizing was 16,7 mg/l lower on average than at the beginning of the tests. The rise in magnesium content caused by the fertilizing was 60,4 mg/l on average compared with the unfertilized soil. This difference in the magnesium content was greatest in test 6 (80 mg/l) and

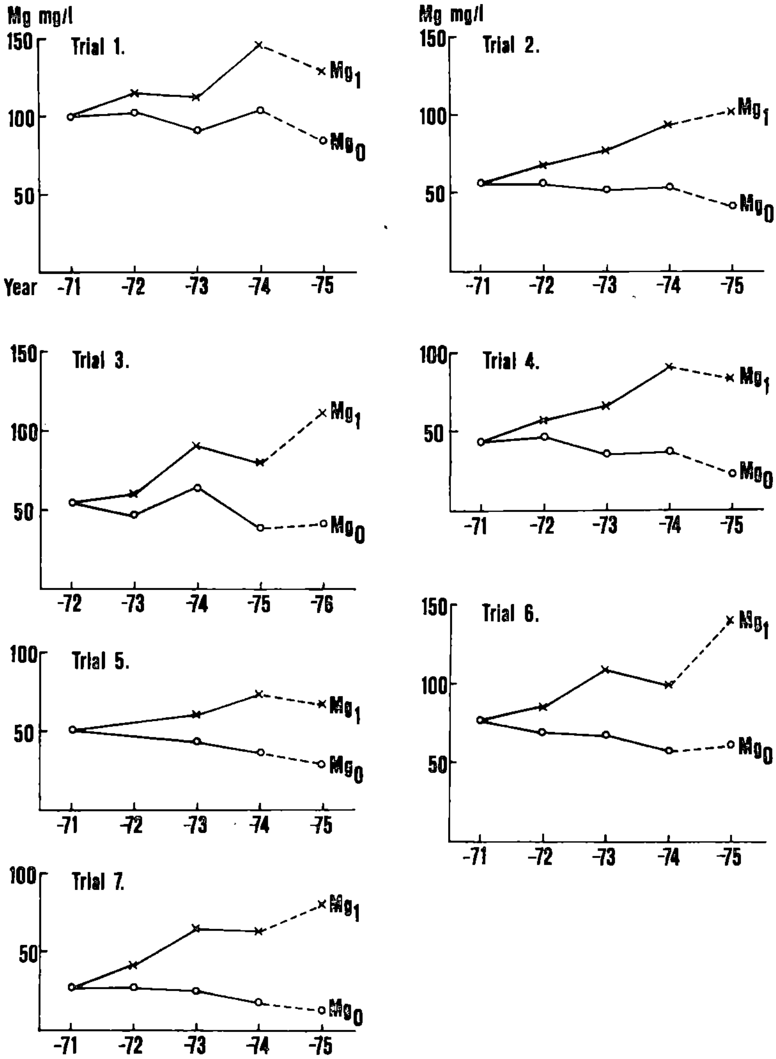

Fig. 1. The average magnesium content of the soil (Mg, mg/l) at various test sites. The samples were taken in the spring before the fertilizers were applied; the samples for the last year were taken in autumn after the harvest.

smallest in test 5 (35 mg/l), although it was statistically significant in all tests (Table 2). The difference in the subsoil magnesium content was 11 mg/l on average. In two tests (4 and 5) the magnesium fertilizing raised the magnesium content (29 mg/l, 24 mg/l) of the subsoil. In other tests this difference (3—10 mg/l) was not significant.

The potassium and nitrogen fertilizer amounts did not affect the magnesium content of the soil, regardless of whether magnesium fertilizer was applied.

The smaller annual application of potassium fertilizing (60 kg/ha K) maintained the potassium content almost at the original level in tests 1, 2, 4 and 5 (Fig. 2). In the other tests the potassium content appeared to decline, particularly when growing grass crops. The larger amount of potassium roughly doubled the initial potassium content of the soil in tests 2, 4 and 5, while the increase was considerably smaller in the other tests.

After the tests the difference between the potassium content of the soil with different potas-

Table 2. The magnesium content of the soil (Mg, mg/l) in the plough layer (a) and in the subsoil (b) after the tests.

Test n:o	K_1				K_4				$LSD_{5\,\%}$	
	N_1	N_1 Mg	N_2	N_2 Mg	N_1	N_1 Mg	N_2	N_2 Mg	K-levels	N- ja Mg-treatments
1. a	90	137	90	126	79	129	74	119	14	31
b	97	108	110	105	94	119	84	83	26	61
2. a	41	104	44	99	42	106	37	97	17	11
b	51	69	87	89	58	71	73	54	20	26
3. a	48	114	41	111	34	118	40	101	10	16
b	22	36	23	24	20	28	23	29	12	12
4. a	24	89	27	94	16	74	20	74	21	9
b	28	63	35	59	21	46	20	51	8	8
5. a	35	65	32	79	24	59	24	64	14	8
b	49	64	49	83	66	106	63	69	37	42
6. a	74	147	52	136	57	125	60	156	29	17
b	73	70	74	86	73	70	68	73	37	23
7. a	11	76	11	94	15	71	14	80	13	23
b	9	13	11	18	12	12	11	13	2	5

Table 3. The potassium content of the soil (K, mg/l) in the plough layer (a) and in the subsoil (b) after the tests.

Test n:o	K_1				K_4				$LSD_{5\,\%}$	
	N_1	N_1 Mg	N_2	N_2 Mg	N_1	N_1 Mg	N_2	N_2 Mg	K-levels	N- ja Mg-treatments
1. a	130	125	106	118	275	275	255	261	36	33
b	68	75	70	75	103	110	93	95	13	28
2. a	68	68	60	55	275	260	256	233	86	47
b	64	60	60	54	95	80	83	88	17	18
3. a	200	183	135	128	420	430	413	398	77	35
b	160	170	170	145	211	263	208	204	22	44
4. a	118	133	83	88	413	395	355	419	70	41
b	75	88	61	63	235	210	178	210	78	49
5. a	148	153	108	105	325	348	348	339	41	33
b	73	63	59	63	119	125	128	118	35	32
6. a	108	115	98	103	293	285	285	295	23	41
b	60	65	43	43	173	126	198	165	24	44
7. a	83	68	75	70	255	265	298	249	38	61
b	70	73	56	53	183	138	119	128	29	43

sium fertilizer amounts was statistically significant at all sites (Table 3). This applies to both the plough layer and the subsoil. At two test sites (3 and 4) the increase in nitrogen fertilizing caused a decline in the potassium content of the soil in the plough layer.

Yields

The effect of the magnesium fertilizing at the different test sites on the annual yields obtained was minor (Table 4). A significant increase in yields was obtained with magnesium treatment in test 3 (1st and 2nd years), test 4 (3rd year) and 5 (1st year) only. A fourfold increase in potassium fertilizing caused a significant increase in yield in test 3 (1st year), and the yield declined in test 4 (4th year). An increase in nitrogen fertilizing from 50 kg to 100 kg at different test sites caused a significant improvement in yield almost every year. The yields from test sites 6 and 7 were an exception, for an increase in the amount of nitrogen had a negative effect in some cases.

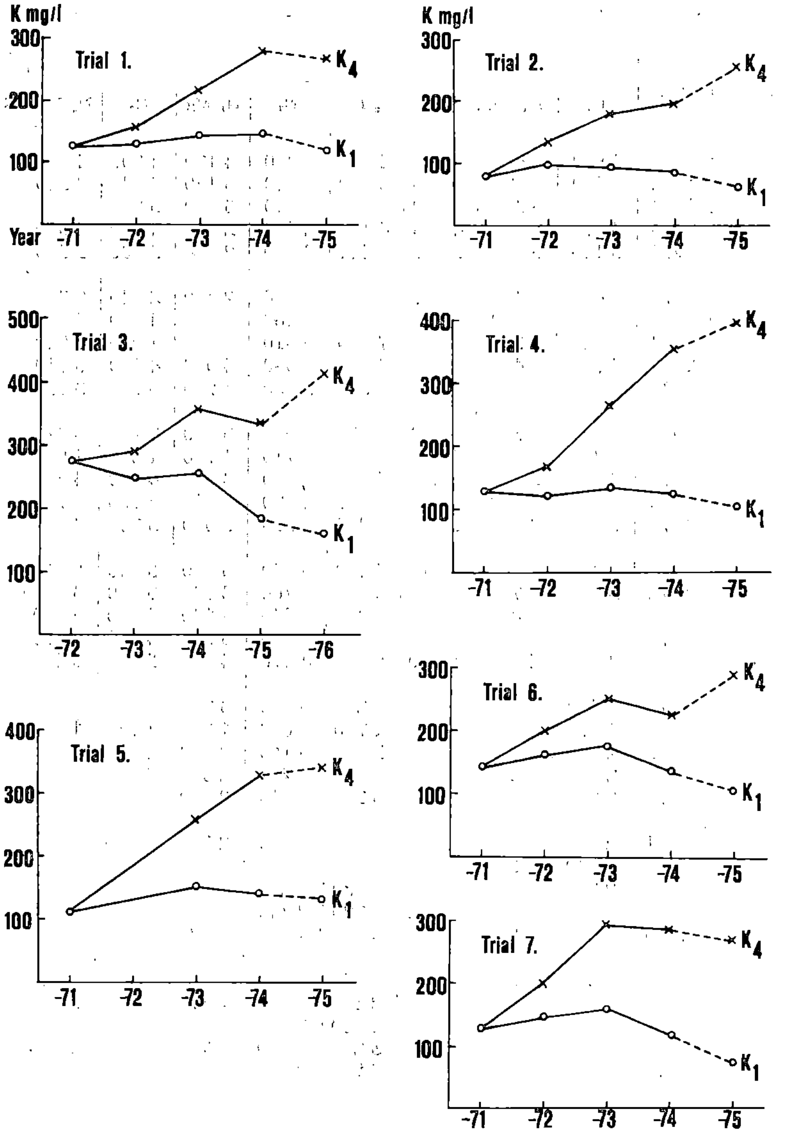

Fig. 2. The average potassium content of the soil (K, mg/l) at different test sites. The samples were taken in the spring before the fertilizers were applied; the samples for the last year were taken in autumn after the harvest.

The mean results obtained at the test sites during the five-year period show that the best yield was in general obtained with the smaller amount of potassium together with the larger amount of nitrogen (Fig. 3). There were differences between the test sites in the effect of magnesium fertilizing. It was possible to offset the decrease in yields caused by the larger amount of potassium using the larger amount of nitrogen fertilizing. In tests 2 and 4 magnesium fertilizing was also needed to achieve the same yield as with the smaller amount of potassium. The need for magnesium fertilizing rose in soils containing little magnesium when the amount of potassium and nitrogen fertilizing was increased. In test 3 the fourfold potassium fertilizing improved the yield.

Table 4. The annual yields (f.u./ha) obtained at different test sites with magnesium, potassium and nitrogen fertilizer.

Test n:o	Plant*)	Year	K_1 N_1	K_1 N_1 Mg	K_1 N_2	K_1 N_2 Mg	K_4 N_1	K_4 N_1 Mg	K_4 N_2	K_4 N_2 Mg	$LSD_{5\,\%}$ K-levels	$LSD_{5\,\%}$ N- ja Mg-treatments
1	b	1971	4 500	4 420	4 730	4 830	4 060	4 130	4 900	4 860	281	181
	o	1972	3 290	3 220	3 160	3 260	3 040	3 120	3 340	3 340	292	331
	l	1973	5 920	5 360	6 080	6 130	5 040	5 010	5 940	5 630	837	859
	l	1974	3 370	2 910	4 030	4 190	2 430	2 420	4 060	4 050	489	524
	o	1975	3 140	3 060	3 400	3 440	2 630	2 610	3 400	3 370	267	316
2	b	1971	2 420	2 400	2 710	2 600	2 670	2 710	2 340	2 340	161	331
	b	1972	4 230	4 260	4 010	3 760	4 180	4 250	4 240	4 270	386	291
	l	1973	6 010	5 870	7 310	7 510	5 310	6 290	7 000	7 040	465	843
	l	1974	4 040	3 490	4 970	4 210	3 340	4 010	4 170	5 710	493	632
	l	1975	3 830	3 820	4 370	3 890	3 680	3 920	3 780	3 690	345	397
3	b	1972	2 320	2 800	3 150	3 220	3 060	3 250	3 220	3 320	191	370
	b	1973	1 310	1 630	1 660	2 060	1 710	1 710	1 670	1 990	305	472
	l	1974	3 070	3 540	4 630	4 230	3 660	3 340	4 160	4 610	712	497
	l	1975	4 150	3 780	5 290	4 530	4 120	4 110	4 780	4 750	1 020	1 076
	o	1976	2 810	3 090	3 190	3 820	3 510	3 030	3 340	3 030	607	238
4	o	1971	5 490	5 340	5 410	5 430	5 490	5 340	5 040	5 460	326	371
	o	1972	3 870	3 710	3 890	3 880	3 760	3 730	3 810	3 770	296	223
	l	1973	3 910	4 040	4 420	4 860	3 540	4 130	3 960	5 230	731	1 076
	l	1974	4 300	4 220	6 070	6 060	3 550	3 840	4 900	5 370	478	623
	o	1975	4 950	4 960	5 410	5 390	4 470	4 600	5 230	5 400	416	393
5	b	1971	3 430	3 510	3 990	4 270	3 090	3 700	3 580	3 840	748	575
	b	1972	1 070	1 210	1 760	1 790	1 050	1 250	1 780	1 700	187	356
	l	1973	2 560	2 820	3 560	3 450	3 160	2 920	4 050	4 350	552	685
	l	1974	2 580	2 640	3 740	3 140	2 240	2 510	3 560	3 660	881	757
	b	1975	2 190	2 200	3 220	3 360	2 010	2 470	3 110	3 210	556	514
6	o	1971	2 950	2 690	2 890	2 900	2 860	2 910	2 060	2 140	1 387	583
	o	1972	3 540	3 530	3 360	3 230	3 530	3 450	3 350	3 530	508	563
	b	1973	2 220	2 620	2 700	2 880	2 210	2 180	2 350	2 500	996	402
	o	1974	2 910	2 920	2 660	2 720	2 740	3 100	2 570	2 720	334	652
	o	1975	2 680	3 000	3 210	3 020	2 670	2 680	2 590	2 680	672	676
7	o	1971	2 570	2 530	1 570	1 830	2 550	2 590	1 630	1 440	330	748
	o	1972	2 090	2 080	2 080	2 130	2 310	2 170	2 180	2 050	531	533
	l	1973	3 390	3 590	3 640	4 140	3 570	3 290	4 250	4 114	396	788
	l	1974	2 910	3 000	3 140	3 290	2 870	2 760	3 500	3 830	849	396
	o	1975	3 090	2 920	2 080	2 520	2 810	2 970	2 070	2 120	432	814

*) b = barley
o = oats
l = ley (hay + aftermath).

Both potassium and magnesium fertilizing in finesand with an admixture of clay,in test 1, reduced the yield when the smaller amount of nitrogen was used.

The following increases in yield (f.u./ha/y) were obtained with magnesium fertilizing at the different test sites during the experiment (mean ± stand. dev.):

Test n:o	Increase in yield f.u./ha/y K_1	K_4	N_1	N_2	Mean	%
1	— 80	— 30	—116	6	— 55±98	1,4
2	—207	352	131	14	73±165	1,7
3	112	— 9	56	47	51±217	1,6
4	17	312	58	271	165±261	3,6
5	29	198	185	42	114±134	4,1
6	39	96	77	58	68±91	2,3
7	147	— 41	26	132	53±74	2,0

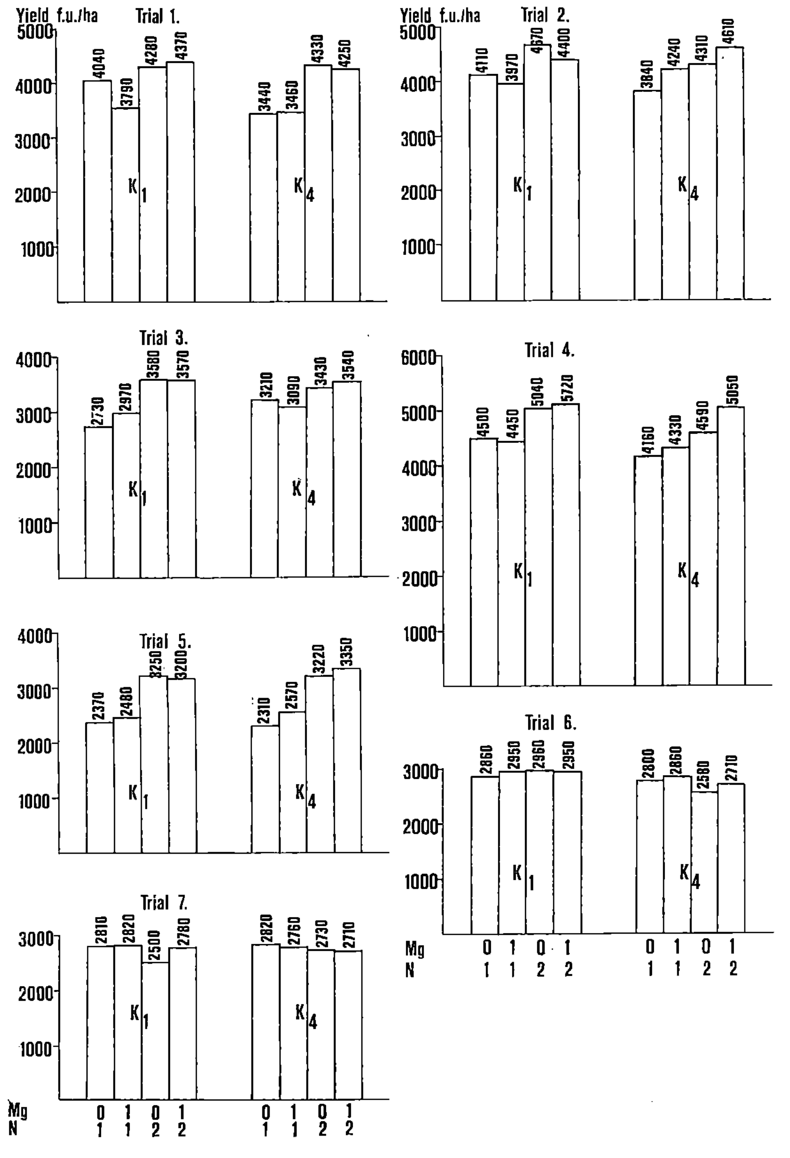

Fig. 3. The average yields (f.u./ha/y) at different test sites with magnesium, potassium and nitrogen fertilizers.

The greatest increases in yield in both absolute and relative terms were obtained in tests 4 and 5. Without magnesium fertilizing the magnesium content of the soil at these test sites declined more during the five-year period than at the other sites. The soils were also acid, and contained little calcium.

The effect of an annual application of magnesium sulphate fertilizer on the yield was most obvious during the third and fourth years, when grass was grown in most of the tests (Fig. 4). The following increases in yield were obtained by magnesium fertilizing in different years at two potassium and two nitrogen levels:

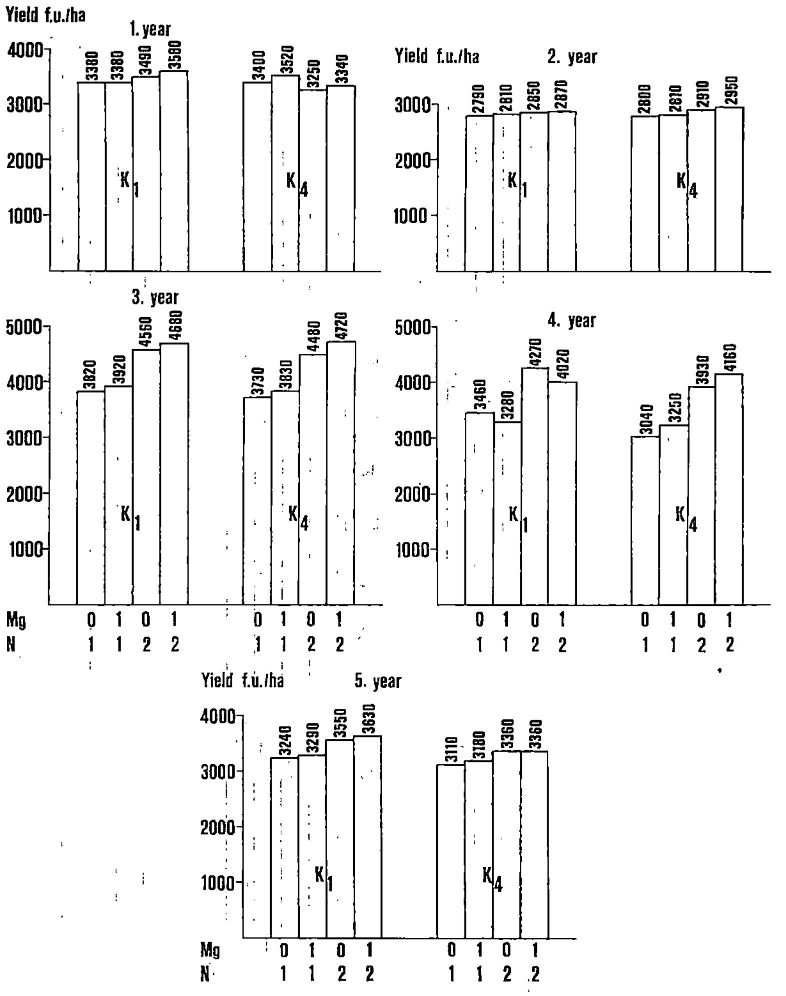

Fig. 4. The average yields (f.u./ha/y) with magnesium, potassium and nitrogen fertilizers for different years.

	K_1	N_2	N_1	K_4	Mean
1st year	45	106	63	89	75±129
2nd year	31	27	24	33	29±112
3rd year	116	174	102	187	145±252
4th year	—217	286	11	58	35±183
5th year	66	34	61	39	50±87

In wet conditions during the fourth test year the magnesium fertilizing decreased the yield at the lower potassium level.

The beneficial effect of magnesium fertilizing on cereals was 68 f.u./ha/y (—60—+308 f.u./ha/y) on average. The increase in yield obtained by magnesium fertilizing was clearer with the smaller amount of potassium than with the larger amount, but was not statistically significant at either level of potassium (Fig. 5). A fourfold increase in the amount of potassium caused a significant reduction in the grain yield (74 f.u./ha/y).

The increase in yield obtained with magnesium fertilizing was in cultivated grass 65 f.u./ha/y (—293—+608 f.u./ha/y) on average. The larger amount of potassium without magnesium produced smaller yields than together with magnesium. However, the increase in yield (300 f.u./ha/y) caused by magnesium fertilizing with a large amount of nitrogen was not significant. In grass crops only an increase in nitrogen fertilizing produced a significant increase in yield.

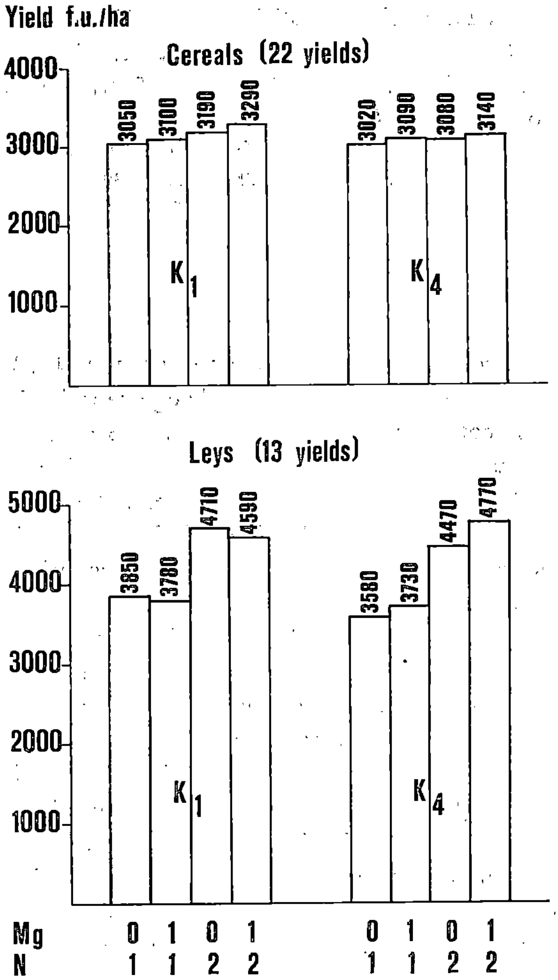

Fig. 5. The effect of magnesium, potassium and nitrogen fertilizers on the yields of cereals and leys (f.u./ha/y).

At two levels of potassium or nitrogen the magnesium fertilizing caused the following increases in yield of cereals and cultivated leys (f.u./ha/y):

	K_1	K_4	N_1	N_2
Cereals	75	65	60	80
Leys	—95	225	40	90

The increase in cereal yield obtained with magnesium fertilizing did not depend significantly on the amount of potassium (r = —0,019) or of nitrogen fertilizing (r = 0,106). The increase in yield of ley crops rose with an increased application of potassium fertilizer (r = 0,455*), while the amounth of nitrogen fertilizer had no significant effect (r = 0,093).

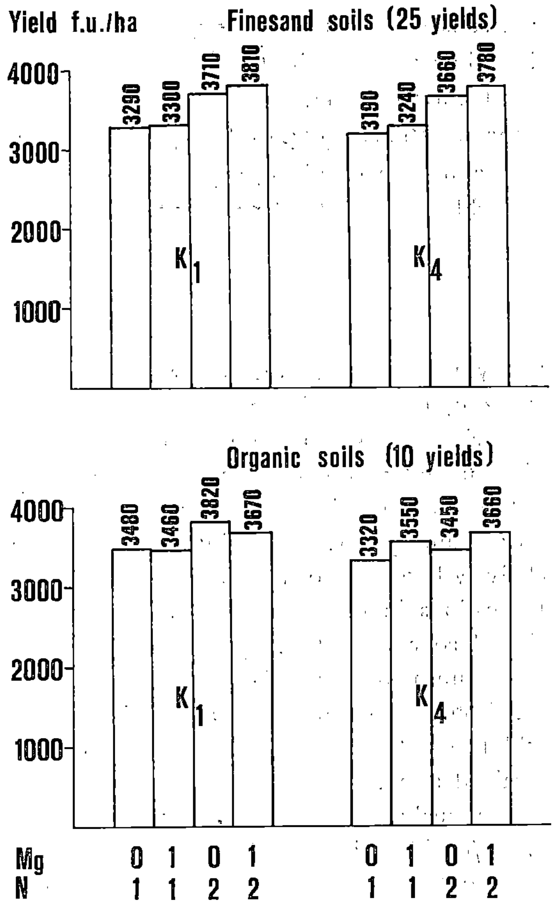

Fig. 6. The effect of magnesium, potassium and nitrogen fertilizers on yield (f.u./ha/y) in finesand, and organogenic soils.

The dependence of the increase in yield obtained with magnesium fertilizing during the first four years of the test period on the magnesium (r = —0,243) and potassium content (r = +0,224) of the soil samples taken in the spring, before the application of fertilizers, was not significant. It was shown for the various plants that the increase in ley crop yield produced by magnesium fertilizing was independent of the magnesium (r = —0,347) and the potassium content of soil (r = +0,204). The increase in cereal yield rose as the potassium content of the soil increased (r = +0,416*), but the magnesium content did not have a significant effect (r = —0,106).

Five of the seven test fields had finesand soil and only two organogenic soils. In the finesand soils magnesium fertilizing had brought a slight improvement in the annual yields obtained with both levels of potassium and of nitrogen fertilizers (Fig. 6). In organogenic soils the magnesium fertilizing appeared to increase the yield only with the larger amount of potassium. Magnesium fertilizing increased the yield in these two soil type groups at the different levels of potassium and nitrogen fertilizing as follows f.u./ha/y:

	K_1	K_4	N_1	N_2
Finesand soils	55	85	30	110
Organic soils	—85	220	105	30

DISCUSSION

Five years of cultivation without magnesium fertilizing led to a decline in the amount of magnesium in the plough layer of finesand soil containing little magnesium. The smallest decrease in magnesium content was in finesand soil containing clay. Magnesium accounts for a relatively large part of the total base exchangeable cations in the clay fractions of Finland's mineral soils (Kaila 1972), and some of this magnesium is readily available to plants (Kaila and Kettunen 1973). Therefore, the increase in yield brought about by magnesium fertilizing remained small.

An annual application of magnesium fertilizer (57 kg/ha Mg) significantly raised the magnesium content of the plough layer at all test sites. The magnesium content below the plough layer increased as a result of the fertilizing only at those sites where the finesand of the plough layer contained little organic matter. At these sites some of the magnesium may have leached to a depth lower than that reached by the sampling. Thanks to its high cation exchange capacity, the organic matter effectively retains magnesium (Kamprath and Welch 1962), and consequently prevents it from leaching. Moreover, the magnesium applied as fertilizer may have been retained in a form that is not soluble in acid ammonium acetate (Henriksen 1964).

If magnesium fertilizing is needed, an amount corresponding to several years' requirement can be applied to organogenic soils as well as to other soils with a relatively high cation exchange capacity. In coarse mineral soils containing little organic matter the smaller amounts of magnesium and frequent applications of fertilizer, perhaps even annually, will probably give the best result. According to Hartikainen (1978) an decrease in the cation exchange capacity in different types of mineral soils appeared to increase both relative and absolute leaching.

Slow-dissolving magnesium, e.g. that accompanying various kinds of liming agents, is not as susceptible to leaching as the magnesium in magnesium sulphate.

In organogenic soils magnesium fertilizing appeared to reduce the yield when the smaller level of potassium was used. The plants are apparently able to make use of even minute amounts of magnesium bound to organic matter (Lombin and Fayemi 1976). A need for magnesium fertilizing is caused only by the larger amount of potassium fertilizer, which the increase in yield obtained with magnesium fertilizing suggests. In finesand soils magnesium fertilizing produced only a slight average increase in yield for all levels of potassium and nitrogen fertilizing.

The level of soil magnesium at which the formation of cereal grain yield is checked is higher than the magnesium content of the soil needed for the formation of the straw yield. A satisfactory grain yield (2 000—3 000 f.u./ha) was obtained without magnesium fertilizing in the test with the lowest magnesium content (26 mg/l Mg) in the material at hand. Neither did magnesium fertilizing in the above case increase the yield significantly. Results of the same kind were obtained by Harris (1977) with barley. According to Reith (1963), the amount of magnesium readily available to plants (extractable in N neutral ammonium acetate) must decline in the soil to below 3 mg/ 100 g before an increase in yield can be expected. The ley yields in BAERUG's (1977) field tests increased significantly with magnesium fertilizing when the magnesium content extractable in the ammonium lactate of the soil was below 4,5 mg/100 g. The magnesium contents of the soil obtained using the above-mentioned solvents are comparable, for each liquid extracts nearly the same amount of magnesium (ANDERSSON 1975).

As the potassium content of the soil rises or when the larger amount of potassium fertilizer is used, the increase in yield obtained with magnesium fertilizing appeared to rise. This suggests an increased need for magnesium fertilizing in soils containing little magnesium when the potassium content of the soil is high or the potassium fertilizing amount is large (FAGERIA 1974). As far as oats are concerned, the greater the application of potassium fertilizing the more the magnesium fertilizing increased the yields of grain and straw in the pot test when the substrate contained little magnesium (JOKINEN 1977 a).

The smaller amount of potassium (60 kg/ha K) used in this test series was not sufficient for ley, for the potassium content of the soil fell during the test period. The decline in potassium content was clearer with the larger amount of nitrogen than with the smaller amount (JOY et al. 1973). As the potassium fertilizing was low, the ley plants did not appear to need the magnesium fertilizing either. Despite the reduction in the potassium content of the soil, the best results were obtained with the smaller amount of potassium fertilizer.

The magnesium fertilizing together with the larger amount of potassium produced the greatest increases in yield on acid finesand soils. Acidity in turn hinders the availability of magnesium (FRIED and NOGGLE 1958), and the magnesium applied as fertilizer prover beneficial. The liming of acid soils of this kind is of great importance (KERÄNEN and JOKINEN 1964), although magnesium fertilizing also appeared to increase the yield.

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SELOSTUS

Magnesiumlannoituksen vaikutus kevätviljojen ja nurmen satoon sekä maan ravinnepitoisuuksiin kahdella kalium- ja typpilannoituksen tasolla

RAILI JOKINEN

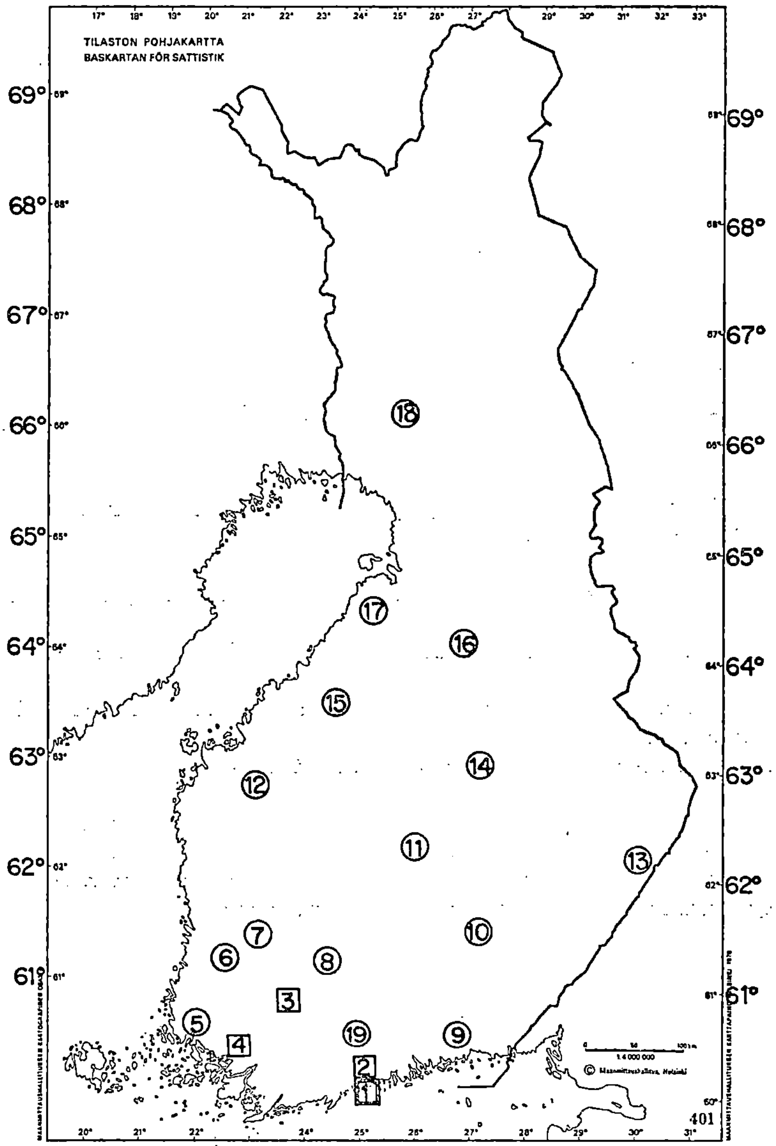
Maatalouden tutkimuskeskus

Kahdella kalium- (60 ja 240 kg/ha K) ja typpilannoituksen (50 ja 100 kg/ha N) tasolla tutkittiin magnesiumsulfaattilannoituksen (57 kg/ha Mg) vaikutusta kevätviljojen ja nurmen satoon sekä maan ravinnetilaan. Viisi vuotta jatkuneen koesarjan aikana lannoitukset annettiin vuosittain. Kasvivuorotus eri koepaikoilla oli seuraava: kahtena ensimmäisenä vuotena vilja, kolmantena ja neljäntenä vuotena nurmi, viidentenä vuotena vilja. Seitsemästä kokeesta kuusi oli maalla, jonka magnesiumpitoisuus oli alhainen.

Keskimääräinen magnesiumlannoituksella saatu viljojen jyväsadon lisäys oli koko aineistossa 68 ry/ha (—60—+308 ry/ha) ja nurmisadon lisäys vastaavasti 65 ry/ha (—293—+608 ry/ha). Magnesiumlannoituksen tuottama sadonlisäys ei riippunut merkitsevästi maan ravinnetilasta. Typpilannoituksen lisääminen kohotti lähes joka vuosi eri koepaikoilla satoja merkitsevästi. Magnesiumlannoituksella saatu sadonlisäys ei riippunut lannoitetypen määrästä, koska suurikaan typpimäärä ei ollut kovin runsas. Maan magnesiumpitoisuuden muutos koekauden aikana ei riippunut typpilannoituksen määrästä. Kaliumpitoisuus näytti laskevan typpeä lisättäessä.

Kaliummäärän lisääminen nelinkertaiseksi aiheutti viljojen jyväsadon ja nurmisadon alenemisen. Nurmille tarvittiin eräissä tapauksissa suuri typpimäärä yhdessä magnesiumlannoituksen kanssa korjaamaan runsaan kaliumlannoituksen negatiivista vaikutusta satoon. Viiden vuoden kuluessa maan kaliumpitoisuus laski pienen kaliummäärän tasolla. Siitä huolimatta tällä kaliummäärällä saatiin runsaimmat sadot. Suuri kaliummäärä kohotti maan vaihtuvan kaliumpitoisuuden muutamilla koepaikoilla kaksinkertaiseksi pienen kaliummäärän tasoon verrattuna.

Vuosittainen magnesiumlannoitus kohotti muokkauskerroksen (0—20 cm) magnesiumpitoisuutta kaikilla koepaikoilla. Koejakson lopussa magnesiumlannoituksen aiheuttama magnesiumpitoisuuden muutos (Mg_1—Mg_0) oli keskimäärin 60,4 mg/l (38—80 mg/l Mg). Ilman magnesiumlannoitusta muokkauskerroksen magnesiumpitoisuus aleni viiden vuoden aikana keskimäärin 16,7 mg/l (13—21 mg/l). Magnesiumlannoitus lisäsi muokkauskerroksen alapuolella (20—40 cm) maan magnesiumpitoisuutta vain niillä paikoilla, joilla muokkauskerros sisälsi vähän orgaanista ainetta. Lisäys oli keskimäärin 11,4 mg/l (3—29 mg/l).



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