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ANNALES AGRICULTURAE FENNIAE, VOL. 24: 63—69 (1985)
Seria ANIMALIA NOCENTIA N. 118 — Sarja TUHOELÄIMET n:o 118

INFLUENCE OF SUGARBEET AND NON-HOST PLANTS ON A FIELD POPULATION OF *HETERODERA SCHACHTII*

KARI TIILIKKALA

TIILIKKALA, K. 1985. **Influence of sugarbeet and non-host plants on a field population of *Heterodera schachtii*.** Ann. Agric. Fenn. 24: 63—69. (Agric. Res. Centre, Dept. Pest Inv., SF-31600 Jokioinen, Finland.)

The population density of a sugarbeet cyst nematode remained at about 10 eggs + larvae/g soil when sugarbeet was grown during three successive years in the same place. Broadcast planting of non-host cultivars reduced the population density annually as follows: barley 44 %, broad bean 42 %, alfalfa 41 % and rye 36 %. The differences in reduction rates under non-host plants were not statistically significant. In Finland the low rate of population increase and pathogenicity of *Heterodera schachtii* are probably caused by the low soil temperature, the shortness of the growing season and the scarcity of rains during springtime.

Index words: *Heterodera schachtii*, sugarbeet, non-host plant, crop rotation, soil temperature, rain.

INTRODUCTION

Sugarbeet is grown annually on about 33 000 hectares in the southern and western parts of Finland. First discoveries of sugar beet cyst nematode in Finland were made in the late 1950s when ROIVAINEN (1961) found that the cysts of *Heterodera schachtii* had arrived with imported beets. He also reported that the nematodes spread to the fields in the soil washed from the beets in factories. The nematodes overwintered and could increase on sugarbeet under field conditions. The sugarbeet cyst nematode has only seldom continuosly damaged beets grown on infected fields although there have been cysts on roots every year.

The aim of this study was to investigate *H. schachtii* field population levels on a field where the nematode had damaged sugarbeet in 1977. Sugarbeet and non-host plants: barley, broad bean, rye and alfalfa were grown continuously in the same places during the three years 1978—1980. The population density was counted twice a year from soil samples taken in the spring and autumn. The effect of climate on the population increase was also studied. The experiment was planned for four years so that in the last year the experimental area should have been sown with sugarbeet. Unfortunately the field was used for purposes other than agricultural in the fourth year and the experiment had to be interrupted.

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MATERIAL AND METHODS

The field experiment was conducted in a field near the town of Salo (60 30'N, 23 00'E) where the sugarbeet cyst nematode had damaged sugarbeets exceptionally severely in summer 1977. The field had previously been used for sugarbeet for more than five years. The soil was clayey fine sand.

Barley, broad bean, rye and alfalfa were grown as non-host plants and sugarbeet as host plant. Barley, broad bean and sugarbeet were sown in spring 1979. Alfalfa was sown with barley as the sheltering plant in summer 1978. The plants were grown in strips 64 m long and 5 m broad. The strips were side by side on the same field. The growing of all the plants followed standard farming practice for fertilization and weed control.

Soil samples were taken from six plots (10 m × 2,5 m)/plant species in spring after cultivation and in autumn after harvesting. The sampler tube was 25 cm long and 2,5 cm in diameter. One sample consisted of 50 subsamples or cores. The soil was dried at 18—22 °C and mixed thoroughly before the cysts were collected with a Fenwick can from 200 g soil/sample. The numbers of living eggs and larvae enclosed in the cysts were counted using the New Blue R method (SHEPHERD 1962) and are expressed as E + L/g soil in this paper.

Rainfall/day was counted from the measurements of the Finnish Meteorological Institute's station at Piikkiö (30 km from the experimental field) and soil temperatures from measurements of the station at Jokioinen (50 km from the experimental field). The mean soil temperature/day was calculated from the minimum and maximum temperatures at depths of 5, 10 and 20 cm.

The growth period was determined by calculating the heat units. The cumulative sum of heat units was counted using two different base temperatures, +10 °C (HU/10) and +4,4 °C (HU/4,4), so that each hour-degree above the base temperature was counted as one heat unit (HU). Calculation methods are the same as in GRIFFIN's (1981 a) paper.

The cumulative sums of heat units (HU/10) were 9674 in 1978, 11 452 in 1979 and 11 354 in 1980, and with the lower base temperature (HU/4,4) 27 180, 30 492 and 30 343, respectively. The amounts of rainfall were 295, 297 and 423 mm between May 1 and the end of October in the same years respectively. In the summer before the experiment (1977) the HU/10 sum was 9550 and HU/4,4 sum 28 920 and the amount of rain was 345 mm. May 1977 was exceptionally favourable to the sugarbeet cyst nematode. The amount of rain was 66 mm, about 120 % over the long-term mean and the monthly mean of soil temperature was 8,0 °C. In the experimental years the mean soil temperatures were 5,3, 6,7 and 4,9 in May (ANON. 1977—1980) (Fig. 1).

The numerical data were analysed with SPSSX statistics. The linear regression of the population densities on different plant species was calculated against the time. The differences in population estimates on different plant species and for different sampling times were tested with one-way analysis of variance.

The population estimates from the samples taken in autumn are not accurate, because the samples were taken from uncultivated soil just after harvesting, when the new cysts were not mixed homogeneously. The influence of the rye plantings on the nematode population began first in autumn 1978. The rye strip lay fallow during summer 1978. Because the alfalfa was sown with barley as sheltering plant, the nematode population was influenced by both of these two plants during the first experimental summer.

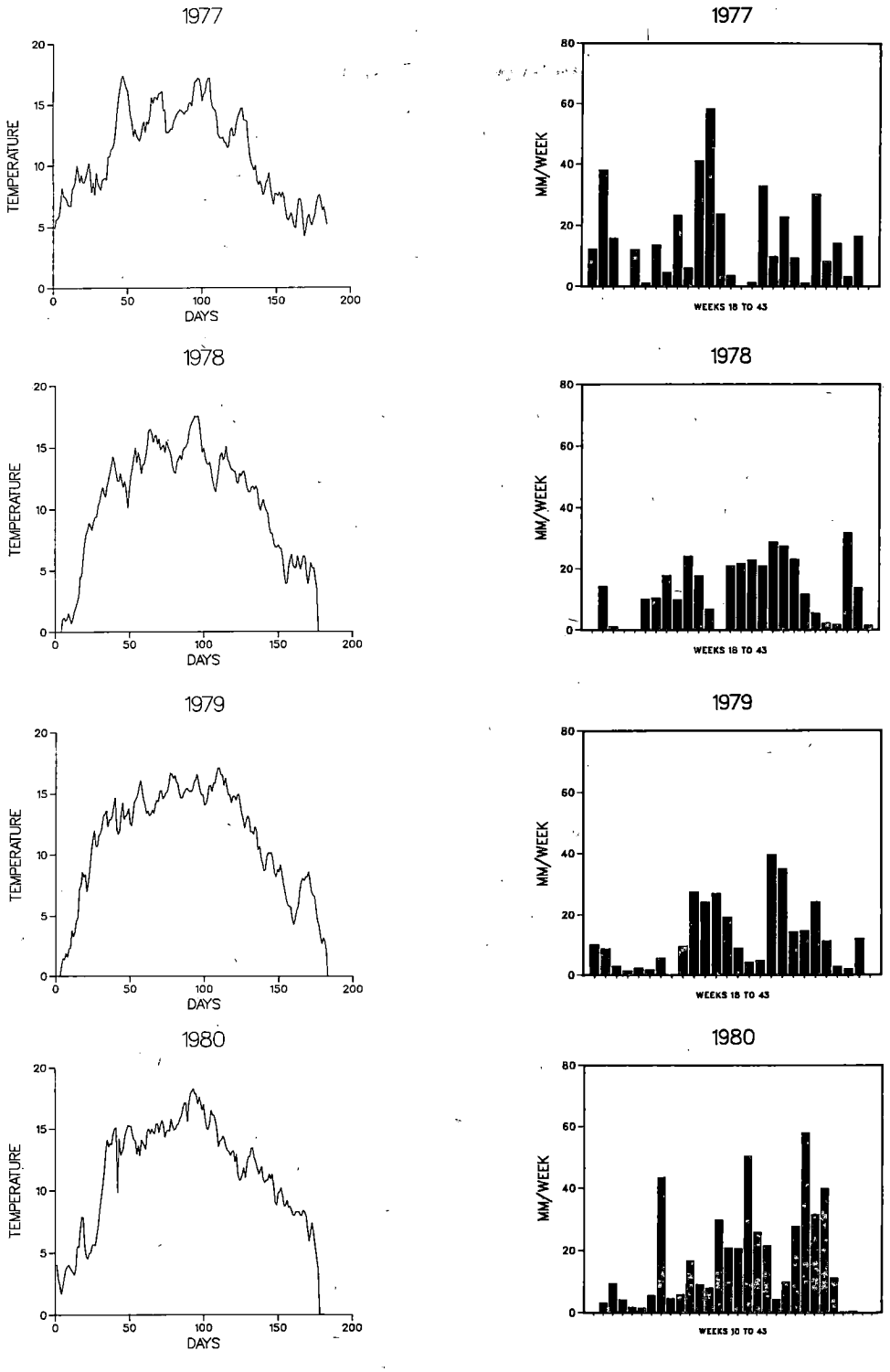

Fig. 1. The daily mean of soil temperature (on the left) and the weekly rainfall (on the right) from the beginning of May to the end of October in 1977—1980.

RESULTS AND DISCUSSION

In the sugarbeet strip the population density of the sugarbeet cyst nematode varied between 6,6 and 18,2 E + L/g soil during the three growing seasons and the regression between the population estimates and the time was not statistically significant (Figs. 2 and 3). The non-host plantings reduced the nematode population so that the population density was significantly lower than the density under the sugarbeet in autumn 1979 and afterwards. The annual reduction rates of the nematode populations were 44 % under barley, 42 % under broad bean, 41 % under alfalfa and 36 % under rye. The nematode populations under the non-host plants did not differ significantly from each other. Hardly any sugarbeet cyst nematodes were found in the barley strip in autumn 1980. The fallow period of the soil in the rye strip did not change the population density in summer 1978.

The plantings of non-host plants decreased the population of sugarbeet cyst nematode about 40 % annually. This reduction is almost the same as the normally found in Europe (JONES 1956). It was assumed that the differences between the effects of non-host plants are insignificant, because the initial population densities were quite low. Barley could be the best plant in crop rotation although its superiority as a non-host plant should be studied more closely. The effect of letting a field lie fallow is also worth studying more precisely under Finnish conditions, because GRIFFIN (1980) obtained different results. He reported that the final population is higher in barley plantings than in fallow soil.

In Finland the soil temperature in spring and summer is lower than in central Europe. According to COOKE and THOMASON (1979) and GRIFFIN (1981 a) such low soil temperatures reduce the development of the sugarbeet cyst nematode and the reductions in yield caused by it. The amount of rain in spring time is low, too.

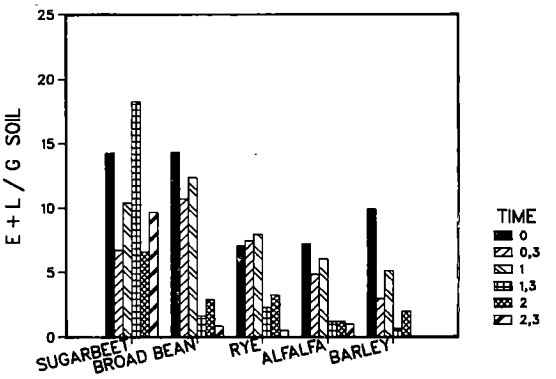

Fig. 2. The population densities of *Heterodera schachtii* under sugarbeet, broad bean, rye, alfalfa and barley in three successive years on the same field. The population densities have been counted from the soil samples taken before sowing in the spring and after harvest in the autumn. The time is presented as years from the first sampling time in May 1978.

van der WAL and VINKE (1982) have reported that low water potential has a direct negative effect on the infection process of cyst nematodes. It is probably due to these unfavourable abiotic factors that population densities of the sugarbeet cyst nematode have remained under the threshold level, 10 E + L/g soil (JAKOBSEN 1980), and yield losses have been small.

The surprisingly visible nematode damage to sugarbeets in summer 1977 was probably caused by the exceptional climatic factors: relatively high soil temperature at the beginning of the summer and the great amount of rain. These factors advanced the migration and infectivity of the larvae and thus increased the damage to the plants. It is known that there can be a seasonal variation in the economic threshold of the pest where the climate is variable (COOKE and THOMASON 1979).

Sugarbeet cyst nematode can increase the effect of plant diseases on cruciferous plants and on sugarbeet (POLYCHRONOPOULOS et al. 1969, INSUNZA and ERIKSSON 1981). As the area under oil seed rapes is increasing in Finland, we should further study the distribution of *Heterodera schachtii*. Different nematode

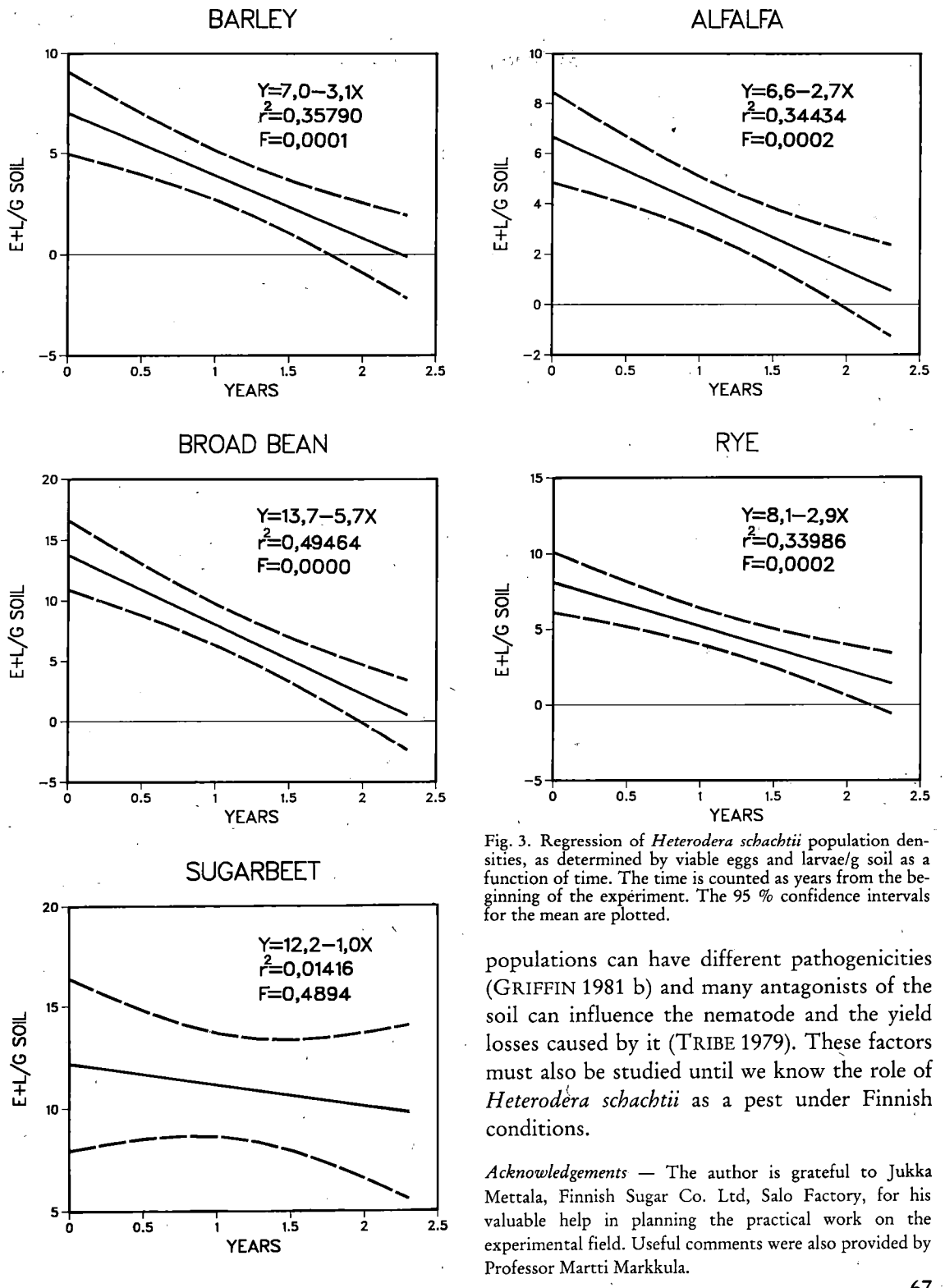

Fig. 3. Regression of *Heterodera schachtii* population densities, as determined by viable eggs and larvae/g soil as a function of time. The time is counted as years from the beginning of the experiment. The 95 % confidence intervals for the mean are plotted.

populations can have different pathogenicities (GRIFFIN 1981 b) and many antagonists of the soil can influence the nematode and the yield losses caused by it (TRIBE 1979). These factors must also be studied until we know the role of *Heterodera schachtii* as a pest under Finnish conditions.

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SELOSTUS

Juurikasankeroisen torjunta vuoroviljelyllä

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Maatalouden tutkimuskeskus

Juurikasankeroinen levisi maahamme tuontijuurikkaiden pesuvesien mukana 1950- ja 1960-luvuilla. Se vioitti sokerijuurikasta vain harvoin ennen kesää 1977, jolloin ankeroisen todettiin alentaneen juurikassatoja monella Salon Sokeritehtaan viljelyksellä.

Tällä tutkimuksella hankittiin tietoja poikkeuksellisten vioitusten syistä, vuoroviljelyn tehosta torjuntakeinona sekä ankeroisen menestymiseen vaikuttavista tekijöistä.

Koe perustettiin pellolle, jolla ankeroisen aiheuttamat satotappiot olivat suurimmat kesällä 1977. Koealueella viljeltiin sokerijuurikasta, ohraa, härkäpapua, sinimailasta sekä ruista kolmen vuoden ajan. Ankeroismäärät laskettiin maanäytteistä, jotka otettiin keväällä ennen kylvöä ja syksyllä korjuun jälkeen kaikkina koevuosina.

Ankeroismäärä pysyi tuhokynnyksen, 10 munaa ja toukkaa/g maata, vaiheilla sokerijuurikasta viljeltäessä. Isäntäkasveiksi kelpaamattomien lajien viljely hävitti juurikasankeroisen lähes täysin kolmessa vuodessa. Ohran viljely laski ankeroismäärää vuosittain 44 %, härkäpavun 42 %, sinimailasen 41 % ja rukiin 36 %. Erot eivät ole tilastollisesti merkitseviä. Voidaan arvioida, että kasvukauden lyhyys ja maan lämpötilan alhaisuus rajoittavat juurikasankeroisen lisääntymistä Suomen oloissa niin paljon, etteivät ankeroismäärät muodostu yhtä suuriksi kuin esim. Keski-Euroopan maissa ja satotappiot ovat meillä harvinaisia jatkuvassakin juurikkaan viljelyssä.

Normaalia näkyvämmät vioitukset kesällä 1977 aiheutuivat todennäköisesti ankeroistoukkien liikkumista edistävis-

tä säistä: suhteellisen korkeasta maan lämpötilasta kasvukauden alussa sekä samaan aikaan tulleista poikkeuksellisen runsaista kevätsateista.

Juurikasankeroisen esiintymistä rypsissä ja rapsissa on seurattava, koska ankeroisen on todettu edistävän maassa olevien sienitautien iskeytymistä niihin. Öljykasvit eivät yleensä kärsi juurikasankeroisen suoranaisesta vioituksesta, vaikka ankeroinen lisääntyykin niissä paremmin kuin sokerijuurikkaassa. Rypsiä ja rapsia ei siten kannata pitää sokerijuurikkaan viljelykierrossa lisäämässä ankeroisia yli juurikkaan tuhokynnyksen.

Tutkimuksen tulokset on julkaistu suomenkielellä Maaseudun Tulevaisuuden liitteessä Koetoiminta ja käytäntö 16.3.1982.

ANNALES AGRICULTURAE FENNIAE, VOL. 24: 71—75 (1985)
Seria AGRICULTURA N. 72 — Sarja PELTOVILJELY n:o 72

FLUCTUATION OF RESERVE CARBOHYDRATES IN TETRAPLOID 'TEPA' RED CLOVER

ANNA-MARI PITKÄNEN and ERKKI HUOKUNA

PITKÄNEN, A-M. & HUOKUNA, E. 1985. **Fluctuation of reserve carbohydrates in tetraploid 'Tepa' red clover.** Ann. Agric. Fenn. 24: 71—75. (Agric. Res. Centre, South Savo Res. Sta., SF-50600 Mikkeli, Karila, Finland.)

The minimum water-soluble carbohydrate (WSC) content in roots of 'Tepa' red clover (5,5 % of the dry matter) was recorded during the spring flush period. The level rose to 20 % at flower-bud stage. Although there was a decline in reserves after each cut, this was followed by replenishment, and the trend continued upward until autumn. In late September, the roots of plants in their first or second harvest year contained about 30 % WSC. The roots of plants in their seeding year had by that time a WSC content approaching 40 %.

During a very long period of snow cover (185 days) there was massive reduction in the carbohydrate content of the roots — from 36 % to 4 % in the seedling crop, and from 31 % to 6 % in a second year stand. In spite of this depletion of reserves, the plants survived the winter remarkably well. Fluctuation of reserve carbohydrates of tetraploid 'Tepa' red clover did not differ from that of diploids recorded elsewhere.

Index words: reserve carbohydrates, tetraploid red clover, overwintering.

INTRODUCTION

The strength of wintering plants are mainly due to the store of water soluble carbohydrates (WSC) in roots and stubble (VIRTANEN and NURMIA 1936, HAFTER 1959). Fluctuations of WSC in the roots of diploid red clovers during the growing season is well known (VIRTANEN and NURMIA 1936, SMITH 1950, HAFTER 1959, PAPE 1968, TAN 1970).

The concentration of WSC in roots is lowest in spring, and remains low while the herbage is expanding rapidly, but rises as the crop matures, reaching a high level before the flower buds open. Maximum levels occur during seed setting, and again in autumn. After each cut, the concentration of WSC, and the amount per plant root, decrease for 2 to 4 weeks, after which they increase again, taking 2 to 6 weeks to regain the previous level: the recovery period is shortest in autumn, when temperature and daylength are declining. During the winter the reserves diminish: if the period of snow cover is too long they may be exhausted. As tetraploid clovers as the first finnish variety 'Tepa' (MULTAMÄKI 1959) are promising for forage production there was need to know how they react to different cutting regimes in order to harden enough to survive also the severe winters.

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MATERIAL AND METHODS

A study was carried out on pure stands of 'Tepa' red clover at the South Savo Research Station of the Agricultural Research Centre in Mikkeli (latitude 61° 40′ N) between May 1980 and May 1981. The soil is fine sand, of medium nutrient status, pH 6,0, and organic matter content about 6 %. Fertilizer applied in 1980 was 300 kg ha^{-1} superphosphate (9 % P) and 200 kg muriate of potash (50 % K). Material was collected from crops in their first and second harvest years growing in adjacent fields, and from a new stand, part of wich was sown with a cover crop and part without. Root samples, 2 replicates of 4 to 15 adjacent plants grown in row, from each treatment were taken weekly to 15 cm depth, washed, and dried at 60 °C for 18 hours. The content of water-soluble carbohydrates (WSC) was determined by the WEINMANN (1947) method.

Portions of both first- and second-year ley were left uncut and these were sampled until the end of July. The first-year ley only was used to compare cutting early (silage stage) and late (hay stage), both to low (5 cm) and high (15 cm) stubble. Aftermath of these comparisons was also cut early and late. The treatments of the seeding year stand without cover crop were: early, medium and late cut (September 1st, 16th and 29th). The stand sown under cover crop was not cut.

Weather

The average monthly temperatures and rainfall in 1980 were:

	°C	mm
May	7,0	55
June	17,2	64
July	16,2	48
August	14,0	158
September	9,5	32
October	3,7	101

The growing season (daily mean temperature ≥ 5 °C) started in 1980 on May 5th and ended on October 20th. The sum of temperature $>$ 5 °C was 1285°.

In September the temperature fell gradually and this, coupled with the low rain-fall, was favourable for the hardening plants. October was very rainy, and snow settled on unfrozen soil on October 24th, the cover lasted until the end of April, i.e. 185 days, and for three months it was at least 60 cm deep. The amount of snow and duration of the cover were well above the average for this location.

RESULTS

The growth of clover herbage was very slow in the beginning of the season 1980. Vigorous growth did not begin until 5 June, and it continued to the middle of July. Rapid growth was also observed at the beginning of August and again in early September. Growth ceased in the middle of September. Regrowth following the silage cut was slower than that following the hay cut, but this may have been due to moisture stress during the post-silage phase. Regrowth from the long stubble was a little better than that following the closer cut.

The weight of the roots increased gradually during the summer. The heaviest root mass was recorded in the second year stand, and the smallest in the seeding-year stand. Carbohydrate content fluctuated widely during the year, even in the intact stands (Fig. 1). Initially it was about 10 %. It remained near that level throughout May, while growth was proceeding

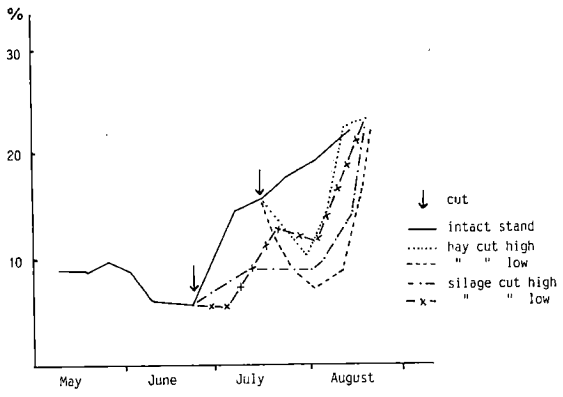

Fig. 1. Fluctuation of WSC content in clover roots in summer. First harvest year stand.

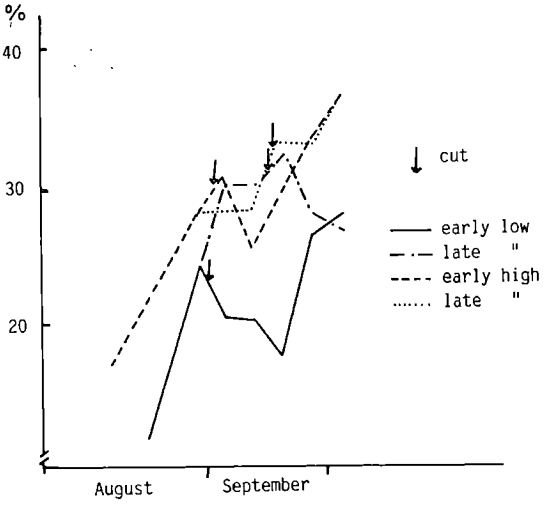

Fig. 2. Fluctuation of WSC content in clover roots after hay cut. First harvest year.

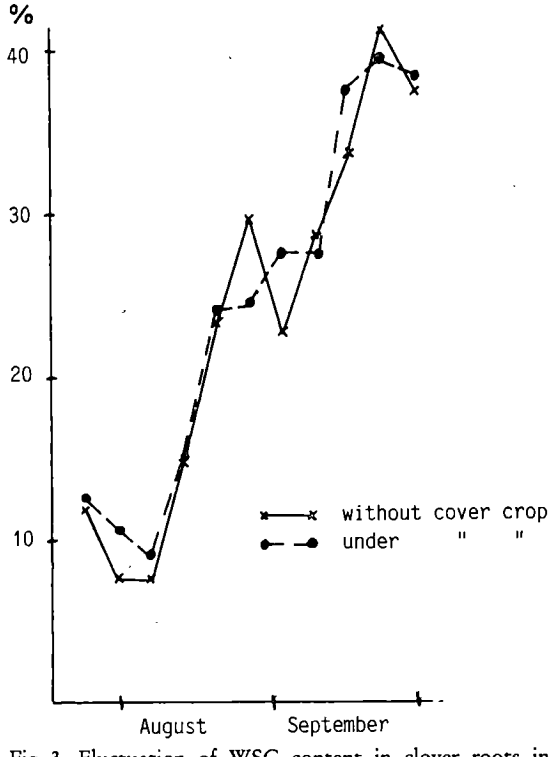

Fig. 3. Fluctuation of WSC content in clover roots in autumn of seeding year.

slowly, but it fell to 5 % during the flush period of growth. Near the flowering stage, root carbohydrate content increased rapidly to about 20 %, where it remained until seed ripening. There was no difference between first- and second-year stands.

The first silage cut was taken when root reserves were very low and for some 3 weeks after this early cut they remained so. The first hay crop, cut when the WSC content had risen to 17 %, reduced it to less than 10 % over the next 3 weeks (Fig. 1). In both cases, WSC then rose to about 23 % by the end of August. In September close cutting again resulted in a sharp drop in carbohydrate content, but it replenished in shorter time than in midsummer (Fig. 2). In autumn the carbohydrate level was 30 % or more.

After hay cut (short stubble) the calculated minimum of carbohydrate content was reached 16,5 days and in autumn 7,6 days after cutting (Figs. 1 and 2). The correlation between mean temperature during the two weeks prior to sampling and WSC-content varied in late summer and autumn in different treatments from −0,79 to −0,92. The highest figure obtained in stand grown under cover crop.

In the newly sown crop the carbohydrate content of clover roots rose rapidly from the beginning of August to October, from about 8 % to 40 % (Fig. 3). Cuts in September resulted in a slight drop and the level remained over 30 %. There was no difference between plants grown with and without a cover crop.

At the last sampling in autumn, October 2nd, there were two levels of carbohydrate content. In plants cut at silage stage, and in plants cut for hay with short stubble, the level was 26—28 %: in the treatment hay cut/long stubble, and in all treatments of the seeding year, the level was 33—38 % (Table 1).

During the long winter 1980/81, a steep drop in carbohydrate content of the roots was recorded (Table 1). The drop was deepest in the clovers of seeding year. In spite of the differences in carbohydrate status in autumn, winter death was negligible in all treatments.

Table 1. Content of soluble carbohydrates in roots of red clover after differential cutting in autumn 1980 and following spring.

Seeding year	Time and height of cutting			Carbohydrate content % in dry matter 2.10.1980	Carbohydrate content % in dry matter 16.5.1981	Drop during the winter %
1979	25.6.	19.8.	low	26,4	7,3	72
	"	"	high	28,6	4,7	84
	15.7.	1.9.	low	28,2	5,0	82
	"	16.9	"	27,3	3,9	86
	"	1.9.	high	36,7	9,0	75
	"	16.9.	"	36,2	6,4	82
1980	1.9.		low	33,6	5,4	84
	16.9.		"	34,9	3,9	89
	29.9.		"	37,6	3,7	90
	in cover crop, no cut			38,6	3,7	90

DISCUSSION

The material of the study is limited but correspond with those from earlier investigations: a low carbohydrate content in spring, a drop after each cut, an increase in autumn and a steep drop during the winter (VIRTANEN and NURMIA 1936, SMITH 1950, TAN 1970, SJØSETH 1971). The WSC content in spring 1980 was extremely low nevertheless the total yield of herbage, over 7000 kg ha^{-1} dry matter was normal.

The WSC content in roots of the newly sown clovers was about 5 units higher than that of the older stands. A similar disparity was noticed by PAPE (1968).

The drop in carbohydrate content after cutting was smoothed by leaving a long (15 cm) stubble in comparison to the low (5 cm). Although the reserves in red clover are not in the stubble the green stem can assimilate and in this way reduce the drain on root reserves (SMITH 1962).

Cover crop barley resulted in less harm to the clover seedlings than elsewhere (TAN 1970). Here the density of barley was about 20 % thinner than normal and the variety 'Eero' has short straw so that even in the ripening phase the clover got enough light for a normal growth.

In grasses the amount of carbohydrates in reserve organs is critical for winter survival (e.g. HUOKUNA 1978), but in clovers it is rather plant diseases that affect the survival of plants. In this case the snow cover was extremely protracted and the drop of reserves was bigger than recorded elsewhere. The fact that the crop survived in spite of those circumstances may have been due to a combination of (a) the favourable autumn weather (especially the gradual decrease of temperature) and (b) that wet snow cover on the plants over the whole winter, which created an almost airless surrounding in which *Sclerotinia* and *Fusarium* could not develop as usual on unfrozen soil.

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SELOSTUS

Hiilihydraattivaraston vaihtelu 'Tepa' puna-apilan juuristossa

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Maatalouden tutkimuskeskus

Kasvit talvehtivat yleensä sitä paremmin mitä suurempi on niiden liukoisten hiilihydraattien varasto. Varaston muodostuminen riippuu jo kesän eri leikkuista, koska joka leikkuun jälkeen varasto vähenee ja tietyn ajan kuluttua nousee entiselle tasolle tai sen ohi. Vaikka tetraploidi 'Tepa' puna-apila poikkeaa monien ominaisuuksiensa puolesta diploideista, oli juuriston hiilihydraattipitoisuuden vaihtelu samanlainen kuin muiden tutkimusten mukaan diploideilla puna-apiloilla.

Leikkuukorkeus ratkaisi juuriston hiilihydraattipitoisuuden palautumisajan pituuden. Lyhyeen sänkeen (3—8 cm) leikattuna oli palautumisaika syksyllä noin kolme viikkoa, pitkään (10—15 cm) sänkeen niitettynä noin kaksi viikkoa. Täksi ajaksi olisi kasvusto rauhoitettava leikkuulta. Kesällä palautumisaika oli noin viikon pitempi.

Kylvövuoden kasvuston hiilihydraattipitoisuus oli suurempi kuin 1-vuoden nurmessa. Lyhytkortinen suojavilja ei häirinnyt hiilihydraattipitoisuuden kehitystä, vaikka apilat jäivät pienemmiksi kuin varjotta kasvaneet. Vararavintovarasto väheni pitkän talven aikana jyrkästi. Siitä huolimatta apilat talvehtivat harvinaisen hyvin, koska ko. kasvustossa ei ollut apilamätää.

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EFFECT OF NITRIFICATION INHIBITORS ON NITROGEN UPTAKE BY BARLEY IN A POT EXPERIMENT

ANTTI JAAKKOLA and TOIVO YLÄRANTA

JAAKKOLA, A. & YLÄRANTA, T. 1985. **Effect of nitrification inhibitors on nitrogen uptake by barley in a pot experiment.** Ann. Agric. Fenn. 24: 77—78. (Agric. Res. Centre, SF-31600 Jokioinen, Finland.)

Nitrogen uptake of barley as affected by two nitrification inhibitors was evaluated in a pot experiment. Nitrapyrin (N-Serve) and ATC were mixed with a sandy soil at a rate of 10 mg of active ingredient per kg of dry soil. Ammonium nitrate labelled with ^{15}N in ammonium or nitrate was applied, raising the soil nitrogen content by 250 mg/kg. Nitrogen uptake was monitored by harvesting test pots at different times.

The uptake of fertilizer nitrogen was nearly complete at a crop age of 1,5 months. The uptake of nitrogen mineralized from the soil still continued during the following three weeks. During the first twenty-five days, plants took up more fertilizer ammonium, but 5 to 10 % more nitrogen derived from nitrate than from ammonium was detected in mature plants. In all, about 60—70 % of fertilizer nitrogen was taken up into the barley tops. In mature plants, about 20 per cent of total nitrogen was derived from the soil.

Nitrapyrin was an effective nitrification inhibitor. Its effect perhaps persisted into the following year. The effect of ATC remained obscure. Nitrapyrin caused a small but significant reduction in grain yield and nitrogen uptake while ATC had no effect. No advantage was created by inhibiting nitrification under these conditions, where leaching was prevented and denitrification losses were small. The average loss of fertilizer nitrogen, regardless of soil treatment, was about 10 per cent.

Index words: nitrification inhibition, nitrapyrin, ATC, ammonium nitrate, labelled nitrogen, barley.

INTRODUCTION

Both ammonium and nitrate nitrogen are available to plants. These forms are always present in the soil because of mineralization of organic nitrogen. The main source of ammonium and nitrate nitrogen in cultivated soils, however, is fertilizers.

Ammonium nitrogen has some advantages over the nitrates as a plant nutrient; the former is not as susceptible to leaching as the latter. In some cases, denitrification may cause substantial losses of nitrate nitrogen. Certainly, ammonium is also lost via special mechanisms. It may be fixed by clay minerals or volatilized as ammonia. Volatilization is unlikely in the acid soils of Finland and the importance of fixation is restricted to some clay soils.

Normally, soil ammonium is rather quickly nitrified to nitrate; for example according to JUNG and DRESSEL (1977) only a few weeks is needed to complete the nitrification. In order to prevent this process nitrification inhibitors have been developed, whose effect is based on their toxicity to nitrifying micro-organisms.

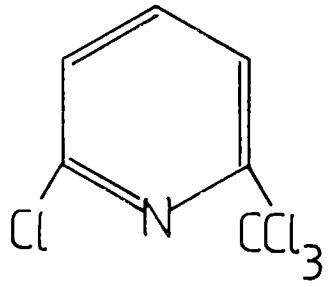
The aim of this study was to follow the uptake of soil and fertilizer nitrogen by barley and to determine the effect of two nitrification inhibitors on it. Differentiation between soil and fertilizer nitrogen was made possible by using ^{15}N labelled ammonium nitrate as fertilizer. A two-year pot experiment was performed.

MATERIAL AND METHODS

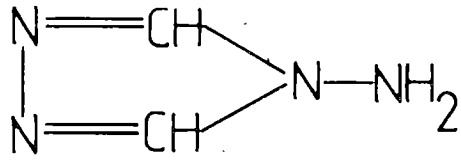
The experimental soil was taken from the plough layer of a cultivated field. The particle size distribution was analysed using the method by ELONEN (1971), total carbon with a dry combustion method (SIPPOLA 1982) and the total nitrogen by the standard Kjeldahl procedure. The soil pH was measured in water and 0,01 M $CaCl_2$ suspensions with a soil to solution ratio of 1:2,5 (v/v). The extractable calcium, magnesium, potassium and phosphorus were determined in an acid (pH 4,65) ammonium acetate extract of the soil (VUORINEN and MÄKITIE 1955). Ammonium and nitrate nitrogen were extracted from the soil with 0,25 M K_2SO_4 and determined colorimetrically. The following results were obtained:

Particle size composition, %:	
$< 2\ \mu m$	11
$2—20\ \mu m$	7
$20—200\ \mu m$	59
Total carbon, % of D.M.	2,6
Total nitrogen, % of D.M.	0,19
Ammonium nitrogen, mg/l soil	4,1
Nitrate nitrogen, mg/l soil	0,9
pH (water)	5,6
pH ($CaCl_2$)	5,2
Extractable Ca, mg/l soil	1550
Extractable Mg, mg/l soil	160
Extractable K, mg/l soil	245
Extractable P, mg/l soil	76

Two nitrification inhibitors were studied. Nitrapyrin is also known by the trade name N-Serve. The chemical name of the compound is 2-chloro-6-trichloromethyl pyridine. Its structural formula is:



ATC or 4-amino-1, 2, 4-triazole was a product from Japan (manufacturer Ishihara Sangyo Kaisha, Ltd.). Its structural formula is:



3,84 kg of soil dry matter was weighed into each pot. Fertilizers containing 400 mg phosphorus, 500 mg potassium and sufficient magnesium, sulphur, copper, zinc, manganese, boron and molybdenum were mixed with the soil. The nitrogen (950 mg/pot or 250 mg/kg soil) was given as ammonium nitrate. Half of the pots were treated with ammonium nitrate

in which the ammonium contained 10 % ^{15}N; the other half received ammonium nitrate in which 10 % of the nitrate was labelled with ^{15}N.

Some of the pots were not treated with any nitrification inhibitor, and some of them were treated with nitrapyrin (10 mg of active ingredient per kg of soil) or ATC (10 mg of active ingredient per kg of soil). The inhibitors were mixed with the soil at the same time as the fertilizers immediately before seeding.

On 14.5.1982, 25 barley seeds (*Hordeum vulgare*, variety 'Pomo') were sown in each pot. The seeds were covered with soil taken from the pot prior to fertilization. The pots were watered to a full water holding capacity. During the growing stage of the experiment the pots were watered daily.

One group of the pots was harvested 25 days after sowing, other groups after 45, 66, 82 and 94 days. ATC treatment was performed only in those groups which were harvested after 45 and 94 days. Each treatment had four replicates.

The tops were harvested by cutting them at the soil surface. The roots were separated from the soil. At the last harvest the mature crop was threshed and the grain and the straw were taken separately. Top, grain, straw and root yields were weighed after drying at 80 °C. Soil samples were taken at each harvesting and deep-frozen.

The pots harvested 25 and 94 days after sowing were kept out-doors but sheltered against rain and snow during the following winter. In spring 1983 the soil of the four replicates of each treatment was combined, mixed thoroughly and divided into four equal portions. The amount of soil in each pot was now 90 per cent of the initial amount. The pots were fertilized with unlabelled ammonium nitrate (1000 mg N per pot) and sufficient amounts of other nutrients.

The barley (variety 'Pomo') was sown on 6.5.1983. The crop was harvested at maturity and threshed. Grain and straw yields were dried at 80 °C and weighed. Soil samples taken at harvest were dried at 30—40 °C.

Plant and soil samples for total nitrogen determination were digested with the Kjeldahl procedure. In order to include the nitrates, salicylic acid and sodium thiosulphate were added to the digestion mixture. Selenium was also added to the soil digests, which were made alkaline with sodium hydroxide and steam-distilled. The ammonia was collected in water containing hydrochloric acid, the volume of which was adjusted by means of a pH indicator so that the solution remained slightly alkaline. After distillation the solution was titrated to neutrality and the total amount of acid consumed was recorded.

The ratio $^{15}N/^{14}N$ in total nitrogen was determined with a mass spectrometer (Micromass 622, manufacturer VG Analytical, U.K.). For the analysis an aliquot of the distillate containing 1,5 mg of nitrogen was evaporated to dryness. The ammonia freed from ammonium chloride in an alkaline environment was allowed to react with sodium hypobromite according to the following formula:

$$2\,NH_3 + 3\,NaOBr \rightarrow N_2 + 3\,NaBr + 3\,H_2O$$

In the mass spectrometer $^{29}N_2$ and $^{28}N_2$ were separated in a magnetic field under reduced pressure (c. 10^{-7} mbar). The atomic ratio $^{15}N/^{14}N$ was calculated from the measured ratio between $^{29}N_2$ and $^{28}N_2$.

Ammonium and nitrate nitrogen were extracted from the soil samples with 0,25 M K_2SO_4. 20 g of soil was shaken for 1 h with 40 ml of the extractant. After centrifuging and removing the supernatant extract the procedure was repeated. The extracts were combined and ammonium nitrogen was steam-distilled from the combined extract made alkaline with magnesium oxide. The ammonia freed from ammonium salts was collected in dilute hydrochloric acid. In a second stage the alkaline extract was treated with Devarda's alloy,

reducing the nitrate to ammonia which again was steam-distilled into dilute hydrochloric acid. The ^{15}N content was determined with a mass spectrometer as reported above. If the amount of total nitrogen was less than 1 mg it was made up by adding unlabelled ammonium chloride in order to facilitate the $^{15}N/^{14}N$ determination with the mass spectrometer.

The contents of nitrogen in the soil as well as the dry matter yields and uptakes of nitrogen are given per unit (kg) of soil dry matter. Determination of the significance of differences between treatments was based on analysis of variance. The difference between individual means was tested according to the Tukey procedure (STEEL and TORRIE 1960, p. 109—110).

RESULTS

At the first harvest 25 d after sowing only a little more than 5 per cent of the final top yield had developed (Table 1). However, the tops already contained at that early stage 20 per cent of the final amount of nitrogen. The uptake of total nitrogen was almost complete at the following harvest (45 d) although just one fourth of the dry matter yield had developed. The increase in dry matter yield continued until 82 d after sowing, but no longer during the last two weeks of the experiment. The root yield was increased until 66 d after sowing but decreased slightly after that. The content of nitrogen in the roots decreased rather clearly except during the last fortnight.

In the second experimental year both the yield and the nitrogen uptake were somewhat higher than in the first year. This was, no doubt, caused by the larger amount of nitrogen available to the crop. The amount of fertilizer nitrogen in the pots harvested at maturity in both years was 950 and 1000 mg/pot or 250 and 290 mg per kg of soil, respectively, in successive years. In the pots harvested at 25 d there was probably some nitrogen left which the first-year crop had not taken up.

The nitrification inhibitors had only a rather slight effect on the dry matter yield and the nitrogen uptake of the crop. Nitrapyrin certainly decreased the final yield of barley in

Table 1. Effect of nitrification inhibitor treatment on the D.M. yield and N uptake of barley.

Growing time (d) in 1982	Treatment in 1982	Yield, g per kg of soil D.M.			N mg per kg of soil D.M.		
		Tops 1982	Roots 1982	Tops 1983	Tops 1982	Roots 1982	Tops 1983
25	Control	1,5^{a}	0,4^{a}	38,6	82^{a}	16^{a}	406
	Nitrapyrin	1,5^{a}	0,4^{a}	39,8	84^{a}	18^{a}	412
45	Control	6,9^{f}	2,5^{f}		203^{g}	36^{f}	
	Nitrapyrin	7,5^{f}	2,5^{f}		201^{fg}	35^{f}	
	ATC	7,1^{f}	2,2^{f}		199^{f}	35^{f}	
66	Control	19,5^{k}	3,5^{l}		219^{l}	33^{l}	
	Nitrapyrin	19,5^{k}	2,9^{k}		210^{k}	28^{k}	
82	Control	26,4^{p}	2,0^{p}		216^{p}	13^{p}	
	Nitrapyrin	26,8^{p}	1,7^{p}		215^{p}	12^{p}	
94	Control	26,0^{v}	2,1^{v}	29,2	212^{v}	15^{uv}	253
	Nitrapyrin	24,3^{u}	1,8^{u}	27,9	196^{u}	14^{u}	241
	ATC	25,8^{v}	2,4^{w}	30,0	211^{v}	17^{v}	238

The values within the same growing time and the same column not followed by a common letter differ significantly ($P > 0,95$).

the first year. Only grain yield was affected and its decrease amounted to about 12 per cent. The uptake of nitrogen by the mature crop was also reduced. Some reduction was already observed at 66 d after sowing. Similar effects could be seen in the root growth and their nitrogen content. ATC very slightly reduced the nitrogen uptake by the crop at 45 d but the top growth was not affected at either dates when ATC treated pots were harvested. At crop maturity the amount of roots was a little increased by ATC.

The effect of nitrogen uptake on nitrogen in the soil is very clearly seen by comparing results given in Table 1 and 2. At 25 d after sowing when only part of the final nitrogen amount had been taken up, the soil contained rather much extractable nitrogen (Table 2). In the soil untreated with any nitrification inhibitor the main part was there as nitrate. Most of that nitrate nitrogen was derived from the fertilizer ammonium and the soil, thus indicating effective nitrification. As a matter of fact, very little fertilizer ammonium was left in its initial form at that stage. The nitrapyrin had obviously rather effectively reduced the nitrification during the first few weeks. At 25 d after sowing there was still a lot of ammonium nitrogen left in the treated soil; most of it was derived from fertilizer ammonium but also substantially from the soil. Only very little ammonium-derived nitrate was present and there was none derived from the soil.

At the crop age of 45 weeks rather little ammonium and nitrate nitrogen were found in the soil. In spite of this, the effect of nitrapyrin was obvious since the low content of nitrate nitrogen was further reduced. The apparent reducing effect of ATC was insignificant.

At the first two harvests the content of nonextractable fertilizer-derived nitrogen in the soil was calculated as the difference between total nitrogen and ammonium and nitrate nitrogen. The content of nonextractable nitrogen derived from fertilizer ammonium did not change between the first and the second harvest. That derived from nitrate was about one third of the ammonium-derived content at the first harvest and increased almost two-fold until the next sampling. The nitrification inhibitors had no effect.

At 66 d after sowing there was so little ammonium and nitrate in the soil that the determination of ^{15}N content was no longer

Table 2. The content of soil nitrogen (NH_4-N, NO_3-N and non-extractable N) derived from fertilizer ammonium and nitrate as well as from soil, mg N per kg dry soil.

Sampling time d	Treatment	Ammonium (125 mg/kg added)			Nitrate (125 mg/kg added)			Soil	
		NH_4-N	NO_3-N	Non-extr. N	NH_4-N	NO_3-N	Non-extr. N	NH_4-N	NO_3-N
25	Control	7^a	36^b	23	2^a	68^a	7	11^a	16^b
	Nitrapyrin	45^b	5^a	22	3^a	62^a	8	19^a	0^a
45	Control	$0,7^f$	$0,4^f$	22	$0,6^f$	$0,7^g$	13	$2,4^f$	$0,8^f$
	Nitrapyrin	$0,7^f$	$0,0^f$	22	$0,6^f$	$0,1^f$	13	$3,7^f$	$0,2^f$
	ATC	$1,6^f$	$0,2^f$	23	$1,0^f$	$0,3^{fg}$	11	$4,3^f$	$0,8^f$
		Total N			Total N			Soil + fertilizer N	
66	Control			22			17	$0,7^k$	$0,1^k$
	Nitrapyrin			24			14	$0,8^k$	$0,2^k$
82	Control			32			23	$1,8^p$	$1,3^q$
	Nitrapyrin			34			24	$2,3^p$	$0,1^p$
94	Control			28			20	$2,3^u$	$2,2^v$
	Nitrapyrin			29			21	$4,2^v$	$0,5^u$
	ATC			29			19	$2,3^u$	$2,0^v$

The contents within the same sampling and the same column not followed by a common letter differ significantly ($P > 0,95$).

possible. The content of both nitrogen forms increased during the last month of growing. Nitrapyrin prevented the increase of nitrate content and enhanced the increase of ammonium content. This was clear evidence of an inhibitory effect of nitrification. ATC did not cause similar differences.

In Table 2, after the sampling at 45 d the total rather than the nonextractable nitrogen derived from fertilizer is given, because the extractable part of the fertilizer-derived nitrogen could not be determined. The main part was in a nonextractable form because the entire fraction of mineral nitrogen including both soil-derived and fertilizer-derived parts was very small. The increase in nitrate-derived nitrogen in the soil continued during this period. The increase in fertilizer-derived nitrogen in the soil between 66 d and 82 d is apparently due to its decrease in the roots. Thus it is obvious that more roots were left in the soil samples at later harvests. The nitrification inhibitors did not have any effect on the fertilizer-derived total nitrogen in the soil.

During the first 25 days of growth the ammonium of the ammonium nitrate was more effectively taken up by the crop from the untreated soil than the nitrate (Table 3). Nitrapyrin eliminated the difference. At 45 d the nitrate had been more effectively utilized by the crop and this difference remained during the rest of the growing time. Nitrapyrin apparently decreased the uptake of ammonium, but significantly only at sampling 66 d after sowing.

In general, the differences in nitrogen uptake by the crop were accompanied by contrasting differences in contents of fertilizer nitrogen left in the soil. Thus, only occasional differences in nitrogen losses were found. The loss was

Table 3. The utilization by barley of the ammonium (NH_4) and nitrate (NO_3) parts of the ammonium nitrate mixed with the soil (250 mg N per kg soil) in spring 1982, %.

Growing time (d) in 1982	Treatment	N form	Year 1982				Year 1983		
			Tops	Roots	Soil	Loss	Tops	Soil	Loss
25	Control	NH_4	32^{c}	6^{ab}	54^{a}	8^{a}	38^{a}	16^{b}	0
		NO_3	23^{a}	5^{a}	62^{b}	10^{a}	50^{b}	10^{a}	2
	Nitrapyrin	NH_4	30^{bc}	6^{b}	58^{ab}	6^{a}	35^{a}	21^{c}	2
		NO_3	28^{b}	5^{ab}	59^{ab}	8^{a}	50^{b}	8^{a}	1
45	Control	NH_4	63^{f}	10^{g}	20^{g}	7^{f}			
		NO_3	72^{g}	9^{fg}	11^{f}	8^{fg}			
	Nitrapyrin	NH_4	61^{f}	9^{fg}	19^{g}	11^{g}			
		NO_3	73^{g}	9^{fg}	11^{f}	7^{f}			
	ATC	NH_4	61^{f}	8^{f}	21^{g}	10^{fg}			
		NO_3	70^{g}	11^{g}	10^{f}	9^{fg}			
66	Control	NH_4	67^{l}	9^{l}	17^{l}	7^{k}			
		NO_3	73^{m}	7^{k}	13^{k}	7^{k}			
	Nitrapyrin	NH_4	61^{k}	8^{kl}	20^{l}	11^{l}			
		NO_3	72^{m}	7^{k}	11^{k}	10^{kl}			
82	Control	NH_4	64^{p}	3^{p}	26^{q}	7^{p}			
		NO_3	71^{q}	3^{p}	19^{p}	7^{p}			
	Nitrapyrin	NH_4	62^{p}	3^{p}	28^{q}	7^{p}			
		NO_3	73^{q}	3^{p}	19^{p}	5^{p}			
94	Control	NH_4	62^{uv}	4^{u}	23^{v}	12^{uv}	$3,2^{v}$	19^{v}	0
		NO_3	72^{w}	3^{u}	16^{u}	9^{u}	$2,2^{u}$	13^{u}	0
	Nitrapyrin	NH_4	56^{u}	4^{u}	24^{v}	16^{v}	$3,7^{v}$	22^{w}	—2
		NO_3	68^{vw}	3^{u}	17^{u}	12^{uv}	$2,4^{u}$	14^{u}	1
	ATC	NH_4	63^{uv}	4^{u}	24^{v}	9^{u}	$3,3^{v}$	20^{vw}	0
		NO_3	69^{vw}	4^{u}	15^{u}	12^{uv}	$2,3^{u}$	14^{u}	—1

The percentages within the same growing time and the same column not followed by a common letter differ significantly ($P > 0,95$).

calculated by subtracting the nitrogen in the tops, roots and soil from the added amount.

Nitrapyrin seems to have particularly increased the loss of fertilizer ammonium, but the losses at different harvests are somewhat illogical. The losses were certainly not very high, varying at crop maturity from 9 to 16 per cent in different forms of fertilizer nitrogen and different treatments.

In the second year of the experiment, 13—15 per cent of the nitrogen left in the soil after growing the barley until maturity was taken up by the crop. The available portion did not depend on whether it was derived from the ammonium or the nitrate part of the fertilizer. Thus, after the second crop there was in the soil still more nitrogen derived from the fertilizer ammonium than from the fertilizer nitrate. In the soil treated with nitrapyrin the content of ammonium-derived nitrogen was somewhat increased.

The second-year crop rather effectively took up the fertilizer nitrogen which was left in the soil after harvesting the first-year barley at 25 days. In autumn 1983 the content of fertilizer nitrogen in those pots was not larger than in pots where two mature crops had been harvested. Even now more ammonium-derived than nitrate-derived nitrogen was present, although the opposite was true in the previous autumn. More ammonium-derived nitrogen was left in the soil treated with nitrapyrin than in the untreated soil.

DISCUSSION

During the first 25 days of this pot experiment, when only 5 per cent of the final dry-matter yield had developed, ammonium-derived nitrogen had been more available than nitrate-derived nitrogen in the untreated soil. According to soil analysis nitrification was almost complete. Thus, a notable portion of ammonium-derived nitrogen must have been taken up as nitrate. Competition between this nitrate and nitrate-derived nitrate may have depressed the uptake of the latter. This assumption is further supported by the fact that the difference in availability of those nitrogen forms was almost eliminated when nitrification was inhibited. Ammonium was as good a nitrogen source for barley as nitrate during this period.

The uptake of fertilizer nitrogen was completed in 1,5 months. The recoveries of fertilizer ammonium and nitrate in barley tops were about 60 and 70 per cent, respectively. These percentages were higher than in many pot, lysimeter and field experiments with a cereal crop reported by other workers (JANSSON 1963, MBA-CHIBOGU et al. 1975, BECKER et al. 1977, DOWDELL et al. 1980). In their studies the utilization varied from 24 to 57 per cent. However, according to STREBEL et al. (1980) spring wheat utilized 81 per cent of nitrogen added as calcium nitrate. There are examples in the literature where, as in this study, nitrate has been a more effective nitrogen source for the crop than ammonium (JANSSON 1963, MBA-CHIBOGU et al. 1975), but also opposite differences have been found (BECKER et al. 1977). In all studies referred to, $(NH_4)_2SO_4$ and $Ca(NO_3)_2$ or $NaNO_3$ have been used as fertilizers. In this study where NH_4NO_3 was used the competition between ammonium and nitrate in plant uptake was, no doubt, a very important factor.

The cessation of fertilizer-nitrogen uptake was accompanied by exhaustion of its reserves in mineral form in the soil. The main part of the fertilizer nitrogen which the plant had not taken up in its tops (c. 60—70 %) and roots (c.

10 %) was left in the soil (c. 10—20 %) from where it could not be extracted with K_2SO_4. The loss or amount not accounted for was about 10 per cent at that stage. Because no leaching was possible with this experimental technique the losses must have taken place through volatilization. Volatilization (denitrification) losses within the range 10—20 per cent have been observed e.g. in experiments reported by JANSSON (1963) and DOWDELL and WEBSTER (1984). In a lysimeter experiment reported by BECKER et al. (1977) the loss was substantially higher, 26—27 %. On the other hand, STREBEL et al. (1980) found no loss at all in their field experiment with spring wheat. In most of the studies referred to, the fertilizer ammonium or nitrate remaining in the soil after crop uptake was not extractable. However, 13 per cent of the nitrate fertilizer given in a field experiment with barley by BECKER et al. (1977) was still detected as nitrate at the end of the growing season.

Because only traces of mineral nitrogen were left in the soil after 1,5 months due to crop uptake, the rate of nitrification remains obscure. Unfortunately, that sampling was the first opportunity to see the effect of both nitrapyrin and ATC. In spite of the very small contents of ammonium and nitrate nitrogen in soil, nitrapyrin still clearly decreased the latter, indicating inhibition of nitrification. According to JUNG and DRESSEL (1977) the effect of nitrapyrin at the application rate used (10 mg/kg) must have lasted far beyond this time. ATC did not have any significant effect on soil mineral nitrogen and its efficiency in inhibiting the nitrification remained unproved. However, according to other studies (BUNDY and BREMNER 1973, CUTHRIE and BOMKE 1980, MAFTOUN et al. 1981) ATC was also most probably effective during this period.

The blocking of nitrification did not decrease the losses of ammonium-derived nitrogen. On the contrary, the loss was increased from 7 to 11 and 10 per cent due to nitrapyrin and ATC treatment, respectively. Denitrification was most likely not the cause of the losses.

The utilization of ammonium-derived nitrogen in particular was lower in the soil where nitrification had been blocked by nitrapyrin. The decreased utilization was accompanied by increased losses. The reduction in grain yield due to nitrapyrin treatment may partly depend on this lowered availability of nitrogen. On the other hand, nitrapyrin has been found to be phytotoxic at least to some leguminous plants at the application rate used here (MAFTOUN et al. 1981), and the reduced nitrogen uptake may be rather the effect than the cause. ATC affected neither the nitrogen uptake nor the dry-matter yield. ATC showed a far lower phytotoxicity than nitrapyrin in studies by MAFTOUN et al. (1981).

The second-year crop took up various amounts of residual fertilizer nitrogen. The nitrate-derived nitrogen left in soil where the previous crop had grown for 25 d was very available. Its uptake equalled the amount of nitrate-derived nitrate in soil in the previous autumn. The uptake of ammonium-derived residual nitrogen was slightly more than the total amount of ammonium-derived ammonium and nitrate in the untreated soil but less in the soil treated with nitrapyrin. In the latter case the main part of mineral nitrogen had been in ammonium form at the harvest of the previous crop. The reduced availability to the next-year crop and larger amount remaining in the soil after it indicate indirectly that nitrification had been retarded at least until sowing. JUNG and DRESSEL (1977) gave an example of 10 mg/kg of nitrapyrin preventing nitrification for 7—8 months. This duration would be long enough to explain the result observed because during the winter nitrification was not possible in the frozen soil. According to JUNG and DRESSEL (1977) the duration differs markedly in various soils, so it may be even longer than 7—8 months.

The proportion (14—15 %) of residual

nitrogen taken up by the plant after the mature crop was independent of treatment with nitrification inhibitor and of the nitrogen form it was derived from. Thus it seems likely that the residual nitrogen was in the same or a similar form in every case. In this respect the result is different from those published by JANSSON (1963). In his pot experiment the residues of fertilizer nitrate were more available to the plant than those of fertilizer ammonium; he concluded that fixing of ammonium by clay minerals may be the reason. It seems likely that no such fixation occurred in the relatively coarse-textured soil of this experiment and the residual fertilizer nitrogen was in the soil in organic form independently of its source. BECKER et al. (1977) stated that ammonium was incorporated into organic form more quickly than nitrate. This is in good agreement with the present study where most of ammonium immobilization took place within 25 days. In fact, the process was most likely even quicker, since inhibition of the rapid nitrification had no effect. Some doubt about the clay fixation therefore still exists. According to KOWALENKO (1978, 1980) clay-fixed ammonium might behave similarly. Regardless of the procedures involved, immobilization of ammonium was preferred to that of nitrate. This might be the main reason for the lower availability of the former.

The crop in this pot experiment also took up nitrogen derived from soil; in the first 45 days its proportion was about 17 per cent of total nitrogen uptake. The uptake of soil nitrogen still continued during the three following weeks, reaching 20 per cent of the total nitrogen uptake. The treatment with nitrification inhibitors did not change these percentages.

CONCLUSION

Nitrapyrin mixed thoroughly with a sandy soil at a rate of 10 mg active ingredient per kg of dry soil inhibited nitrification of fertilizer ammonium during at least one whole growing season. No advantage was caused in the conditions prevailing in the pot experiment where losses through leaching were not possible and no marked denitrification losses occurred. On the contrary, there was some yield depression due to nitrapyrin treatment, which might be effected by retarded availability of ammonium nitrate fertilizer or a direct phytotoxicity. ATC did not have any effect on the yield or the nitrogen uptake. The experiment failed in showing its effect on nitrification.

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SELOSTUS

Nitrifikaation estämisen vaikutus ohran typenottoon astiakokeessa

ANTTI JAAKKOLA ja TOIVO YLÄRANTA

Maatalouden tutkimuskeskus

Maassa oleva nitraattityppi on alttiina denitrifikaatio- ja huuhtoutumishäviöille. Ammoniumtyppi on niiltä turvassa, mutta maassa tapahtuva nitrifikaatio muuttaa sen normaalisti melko nopeasti nitraatiksi. Ammoniumtypen häviöiltä ilmeisesti vältyttäisiin, jos nitrifikaatio kyettäisiin estämään. Tällä saattaisi olla suuri merkitys, sillä taselaskelmien perusteella on todettu vähintään kolmanneksen pellolle levitetystä lannoitetypestä joutuvan hukkaan.

Astiakokeessa selvitettiin kahden nitrifikaationestäjän, nitrapyriinin (N-Serve) ja ATC:n, vaikutusta ohran typenottoon. Typpilannoitus, joka annettiin ammoniumnitraattina, nosti maan typpipitoisuutta noin 250 mg/kg. Typenottoa seurattiin korjaamalla sato koeastioista eripituisten aikojen kuluttua kylvöstä.

Ohran typenotto ^{15}N:llä merkitystä lannoitteesta lisääntyi lähes tasaisella nopeudella 1,5 kuukauden ikään saakka. Tämän jälkeen kasvi ei ottanut enää lannoitetyppeä, mutta maasta mineraloituneen typen otto jatkui. Ensimmäisten kolmen viikon aikana kasvi otti lannoitteen ammoniumtyppeä enemmän, mutta tuleentunut kasvusto sisälsi nitraattiperäistä typpeä 5—10 % enemmän kuin ammoniumperäistä. Kaikkiaan noin 60—70 % lannoitteen typestä siirtyi kasvin maanpäällisiin osiin. Viidennes tuleentuneen kasvin sisältämästä typestä oli maasta peräisin.

Nitrapyriini esti nitrifikaation aluksi miltei kokonaan, ja vaikutus jatkui ainakin tuleentuneen ohran korjuuseen saakka (3 kk), mahdollisesti osittain seuraavaan vuoteen. ATC:n vaikutus lienee ollut vähäisempi ja lyhytaikaisempi. Nitrapyriini vähensi jyväsatoa ja kasvien typenottoa. Nitrifikaation estymisestä ei ollut etua, sillä ammonium ja nitraatti olivat lähes samanarvoisia tässä kokeessa, jossa nitraatin huuhtoutumistappio estettiin. Koeolot eivät suosineet denitrifikaatiotakaan. Lannoitetypen häviö oli koekäsittelystä riippumatta keskimäärin 10 %. Maahan jääneestä lannoitetypestä osa oli seuraavan vuoden kasvin otettavissa.

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ANNALES AGRICULTURAE FENNIAE, VOL. 24: 89—95 (1985)
Seria PHYTOPATHOLOGIA N. 99 — Sarja KASVITAUDIT n:o 99

THE PREVENTION OF *BOTRYTIS CINEREA* AND *SCLEROTINIA SCLEROTIORUM* ON CARROTS DURING STORAGE BY SPRAYING THE TOPS WITH FUNGICIDE BEFORE HARVESTING

RISTO TAHVONEN

TAHVONEN, R. 1984. **The prevention of *Botrytis cinerea* and *Sclerotinia sclerotiorum* on carrots during storage by spraying the tops with fungicide before harvesting.** Ann. Agric. Fenn. 24: 89—95. (Agric. Res. Centre, Inst. Pl. Path., SF-31600 Jokioinen, Finland.)

Spraying the tops of carrots before harvesting with benomyl, thiophanatemethyl or vinclozoline reduced or prevented decay of the carrots caused by *Botrytis cinerea* and *Sclerotinia sclerotiorum* during storage. The best time to treat the tops was the day before harvesting. The quantity of fungicide residues in the crop was the smallest at that time, the quantities increasing with the time between spraying the tops and harvesting, from one to seven days. However, in all cases the highest residue levels detected were lower than the maximum levels permitted in foodstuffs.

Index words: carrot, storage disease, *Botrytis cinerea, Sclerotinia sclerotiorum,* benomyl, thiophanatemethyl, vinclozoline, fungicide residue.

INTRODUCTION

Botrytis cinerea Pers. ex Fr. and *Sclerotinia sclerotiorum* (Lib.) de Bary are two of the most common and economically important pathogens causing damage to carrots during storage in Finland (MUKULA 1957). Since the tecnazene preparation was withdrawn from use, no new methods have become available for the control of these fungi in practice. Careful handling of the carrots to prevent mechanical damage, providing optimum storage conditions by means of humidification and cooling equipment, and the adoption of crop rotation, are the only practical methods of controlling these pathogens so far developed.

B. cinerea and *S. sclerotiorum* may be present on the old, damaged leaves of carrots during the growing season (ÅRSVOLL 1969). Although no detailed studies have been made into the way these pathogens cause infection (MUKULA 1957, ÅRSVOLL 1969), it can be assumed that infection of the roots mainly takes place from the tops under mechanical topping during harvesting. The aim of this study was to evaluate the possibilities for controlling these storage pathogens by spraying the tops of the carrots before harvesting.

MATERIAL AND METHODS

Storage trials were carried out at Kangasala in 1977—82 using commercial carrot crops. The tops of the carrots in 2 or 4 m-wide strips were sprayed using a pressure sprayer. Four or six carrot samples (10—20 kg) were removed from the sprayed stands, placed in wooden crates, and stored in the cold store of the grower at a temperature of 0 — +0,5 °C. In 1977 the tops were sprayed 7 days before harvesting with benomyl (Benlate, 50 wp a.i.), benomyl + thiram (Pomarsol Forte, 80 wp a.i.), thiophanatemethyl (Topsin M, 70 wp a.i.), thiophanatemethyl + thiram, and one day before harvesting with benomyl or benomyl + thiram. In 1978 and 1980—82, spraying was carried out one day before harvesting using thiophanatemethyl. Two identical trials were carried out in 1982 (Experiments I and II), the carrots being harvested at an interval of one week. Harvesting was done during the third or fourth week of September, and the stored crop was inspected in the following April.

Field trials were arranged in 1978—82 by the Department of Plant Pathology, University of Helsinki, at Viikki. The tops of the carrots were sprayed with benomyl or vinclozoline 1, 2, 4 and 7 days before harvesting. Each plot consisted of four 4 or 6 m-long rows of carrots. Only the centre two rows were used in the trials, the outer rows being used as border rows. Samples were taken on two occasions for analysis, but in the final results the subsamples have been combined since there were no differences in the degree of infection during the different storage periods. Plastic boxes, each containing 6—8 kg of carrots, were stored in a cold store at +1 °C. The boxes were isolated from each other by means of perforated plastic sheeting (hole spacing about 15 cm, Ø = 1 cm). There were four replications of each treatment. In the first year of experiments, the carrots were analysed in February and April, otherwise at the beginning of April.

The storage weight of the carrots was determined before and after storage, the proportion of healthy and infected carrots being expressed as weight and number percentages. Infection by *B. cinerea* and *S. sclerotiorum* was determined by eye, and when necessary using a stereo microscope. In uncertain cases and other types of damage, a piece of tissue (about 0,5 cm) was taken aseptically from inside the affected carrots, close to healthy tissue, and then cultivated on PDA or corn agar containing 200 ppm streptomycin sulphate. The fungi were identified after growing on the medium for 2—4 weeks.

Only the *B. cinerea* or *S. sclerotiorum* weight or number percentages are presented in the results since none of the other parameters which were measured (e.g. evaporation) showed statistically significant differences, or else the result (marketability) did not differ from the degree of infection. No results are presented for the experiments carried out in Viikki in 1978 and in Kangasala in 1980 because all the carrots were healthy. The results for the degree of infection have been subjected to variance analysis or the t-test.

The amount of benomyl residues in the 1978 crop and the amount of vinclozoline residues in the 1981—82 crops were determined at the State Institute for Agricultural Chemistry. The analyses were carried out either on the day following lifting, or else on samples kept in a deep freeze.

In all other respects, the carrots were grown in accordance with the cultivation techniques normally used in Finland: precision drilling, normal fertilization (1000 kg chloridefree NPK/ha) and chemical herbicide and insecticide treatment. The carrot variety used in the Viikki experiments was 'Nantes Notabene No 20 OE' and in Kangasala 'Fancy OE'.

RESULTS AND DISCUSSION

Botrytis cinerea (Fig. 1) was the most common pathogen found on the carrots. The pathogen varied in abundance from 0 to 30 % from year to year in the untreated carrot lots (Tables 1 and 2). This is the same order of magnitude as obtained in other studies (MUKULA 1975, ÅRSVOLL 1969).

Sclerotinia sclerotiorum (Fig. 2) was almost the only pathogen found on the carrots in 1978/79 and 1981/82 in Kangasala (Table 1), but in the other experiments it was either completely absent or present in a few random cases only.

Other storage pathogens which produced

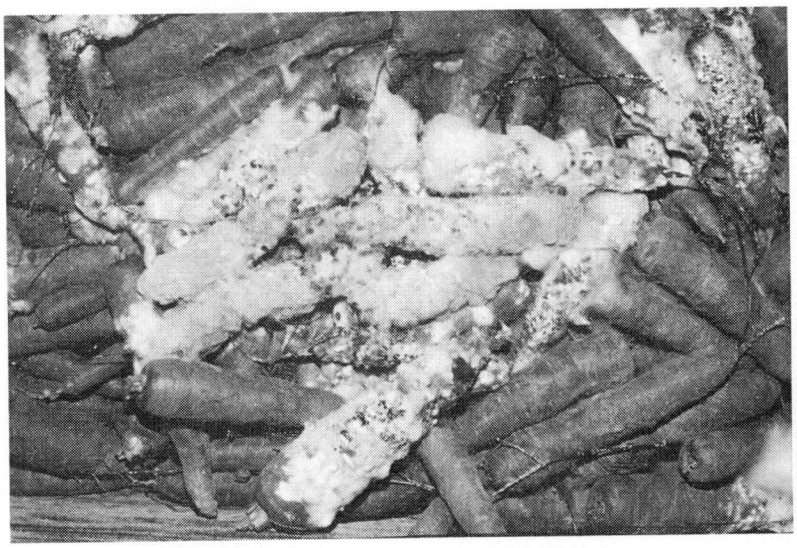

Fig. 1. Carrots spoilt by *Botrytis cinerea.*

Table 1. The effect of fungicide spraying before harvesting on the levels of *Botrytis cinerea* and *Sclerotinia sclerotiorum* on stored commercial carrot crops at Kangasala.

Year	Fungicide	Treatment date, days before harvesting	Degree of infection in spring, percentage weight	
			B. cinerea	*S. sclerotiorum*
1977/78	untreated	—	20,6	0
	benomyl	7	30,6	0
	benomyl + thiram	7	22,4	0
	thiophanatemethyl	7	14,9	0
	thiophanatemethyl + thiram	7	23,4	0
	benomyl	1	2,8	0
	benomyl + thiram	1	2,4	0
	F-value		8,99**	
	$LSD_{t0,05}$		10,6	
1978/89	untreated	—	2,2	41,6
	thiophanatemethyl	1	2,9	0
1981/82	untreated	—	0,9	11,9
	thiophanatemethyl	1	0,1	0
1982/83				
Experiment I	untreated	—	2,7	0,9
	thiophanatemethyl	1	0,1	0
Experiment II	untreated	—	6,2	0
	thiophanatemethyl	1	0,7	0
	t-value		2,67*	

Table 2. The effect of fungicide spraying carried out at different times before harvesting on the levels of *Botrytis cinerea* on stored carrots in Viikki.

Year	*B. cinerea* percentage on stored carrots					
	Untreated	Fungicide a = benomyyli b = vinclozoline	Fungicide treatment, days before harvesting 1	2	4	7
1979/80	10,1	a	14,3	18,2	14,4	9,2
	19,2	b	8,4	8,9	6,2	9,2
1980/81	6,5	a	2,4	5,2	2,0	0,6
	19,7	b	2,9	2,4	0,4	1,5
1981/82	30,7	a	12,8	24,3	21,8	15,6
	30,0	b	17,8	17,8	20,1	16,2
1982/83	2,5	a	1,6	1,2	2,1	10,4
	1,2	b	0	1,3	1,9	1,3

F-values < P 0,05

Fig. 2. Carrots spoilt by *Sclerotinia sclerotiorum.*

black or dark rot on the carrots were usually present on only 0—5 % of the carrots. The most common fungi isolated from these carrots were: *Mycocentrospora acerina* (Hartig) Deighton (syn. *Centrospora acerina* (Hartig) Newhall), *Fusarium avenaceum* (Fr.) Sacc., *Penicillium* spp., *Phoma* spp. and *Stemphylium radicinum* (Meier, Drechsl. & Eddy) Neerg., of which *M. acerina* was the predominant species. A number of unidentified bacteria were also isolated. The fungi found to produce black rot on carrots were similar to those reported elsewhere (ÅRSVOLL 1969, HEINZE 1974). *M. acerina* can be considered a new pathogen in Finland because MUKULA (1957) does not mention it at all in his study. This being the case, research should be carried out on the distribution and biological properties of this pathogen in Finland.

Treating the tops of the carrots in the commercial cultivation at Kangasala one day before harvesting significantly reduced the levels of *B. cinerea* on the stored carrots (Table 1, Fig. 3). During the years 1978/79 and 1981/82, when *S. sclerotiorum* was almost the only pathogen found on the carrots, spraying the tops with thiophanatemethyl reduced the level of pathogens from 43,8 to 2,9 %, and

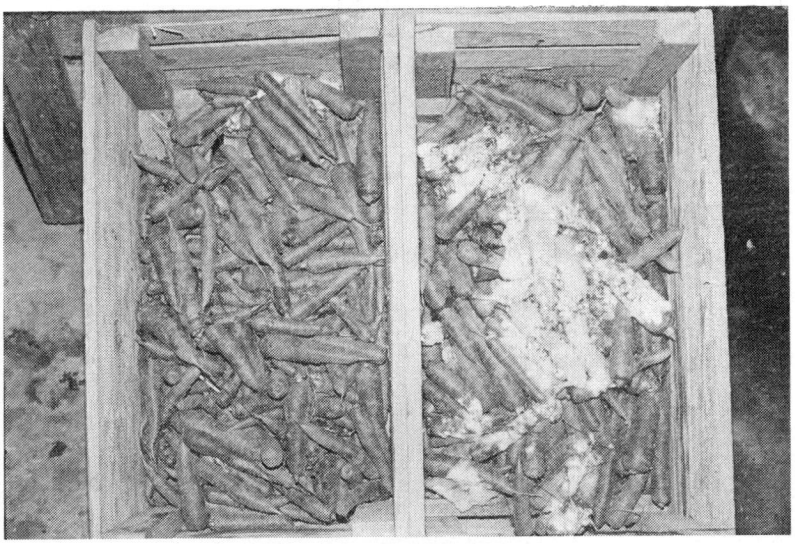

Fig. 3. The control of *Botrytis cinerea* on stored carrots by spraying the tops one day before harvesting. Untreated carrot tops on the right, and tops sprayed with benomyl on the left.

from 11,9 to 0 % respectively. Spraying seven days before harvesting had no effect on the level of *B. cinerea.*

Treating the tops of the carrots also reduced the levels of *B. cinerea* on the stored carrots in the Viikki experiments, although the differences were not statistically significant. The level of *B. cinerea* in the untreated lots inparticular varied in the different replications from a few per cent to as much as 100 %. This weakened the statistical reliability of the results. These experiments were always established in areas where carrots or other vegetables had not earlier been grown. This may be the reason for the irregular variation in the fungus levels on the stored carrots. Another possible explanation is the small size of the sample plots, although the fact that each plot had its own border rows has presumably increased the variation. This phenomenon did not occur in the experiments carried out with the commercial crops. The sample plots were large, and vegetables had been grown on the same area for many years.

The results presented here support the assumption presented in the introduction that the conidia of *B. cinerea* spread from the tops onto the roots in connection with lifting. *B. cinerea* has been shown to be frequently present on the tops (ÅRSVOLL 1979). Spraying the tops with fungicide before harvesting presumably destroys the conidia on the surface of the foliage. This prevents infection of the tubers during lifting. The fungus can obviously rapidly produce new conidia after the effect of the fungicide has declined. This conclusion is supported by the result that treatment carried out one week before harvesting no longer reduced infection of the stored carrots by *B. cinerea.* Long distance dissemination of *B. cinerea* may not be of much importance in autumn during harvesting when the temperature is usually close to 0 °C and the stand is moist almost all the time. The conidia of the fungus have been found to spread poorly at low temperatures and high humidity levels (CHASTANGER et al. 1978). Cutting of the tops of the carrots and the violent shaking caused by this process will naturally free the conidia from the tops and enable them to infect the carrots to be stored.

The benomyl residues in the carrot crops amounted to 0,02—0,04 ppm and the vinclozoline residues 0,04—0,21 ppm. These levels were lowest when the time between spraying and lifting was one day. However, the residue levels were always considerably below the maximum permitted levels for these compounds — benomyl 0,5 ppm and vinclozoline 2 ppm (ANON. 1979). In this study, the lifted crop was not in fact directly treated, only the tops of the crop were affected. The fungicides would thus have to be transported down to the roots mainly along with the water, because systemic fungicides mainly move upwards in the apoplast. In this case the short time between treatment and harvesting has thus decreased the levels of the residues — there was no time for them to move down to the roots.

The method described here for protecting stored carrots against *B. cinerea* and *S. sclerotiorum* would be suitable from the point of view of both the grower and the consumer. Excessive amounts of residues do not accumulate in the stored product, which may in any case disappear during storage lasting for over four months. From the growers' point of view, spraying the tops to control storage pathogens is simple and easy to carry out in practice, especially if harvesting is done mechanically. The risk of storage pathogens is high in mechanical harvesting since the tubers are treated more roughly than in hand lifting. The high level of residues in the tops at harvesting time may, however, affect the suitability of the method for hand lifting — this would presuppose the continuous use of protective gloves.

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SELOSTUS

Varastoidun porkkanan harmaahomeen ja pahkahomeen torjunta ennen sadonkorjuuta tehdyllä naattien fungisidiruiskutuksella

RISTO TAHVONEN

Maatalouden tutkimuskeskus

Porkkanan varastotaudeista harmaahome (*Botrytis cinerea*) ja pahkahome (*Sclerotinia sclerotiorum*) ovat kaikkein yleisimpiä ja useissa tapauksissa taloudellisesti erittäin haitallisia. Näitä tauteja voitiin aikaisemmin torjua säilöntäaineella, mutta säilöntäaineen käytön kiellon jälkeen on ainoana käytännön neuvona ollut kiertoviljely, hellävarainen sadon käsittely ja hyvät varastointiolot. Useimmat varastotaudit, kuten myös harmaahome ja pahkahome, voivat saastuttaa jo kasvukaudella porkkanan vanhimpia naatteja, jotka oletettavasti toimivat pääasiallisena taudin lähteenä varastoitaville porkkanoille. Tämän olettamuksen perusteella aloitettiin 1977 seitsemän vuotta kestäneet tutkimukset, joissa pyrittiin torjumaan porkkanan varastotauteja ennen sadonkorjuuta tehtävin ruiskutuksin.

Sekä käytännön viljelmällä että koekentällä Viikissä tehtiin naatistoruiskutuksia benomyylillä (Benlate), tiofanaattimetyylillä (Topsin M) ja vinklotsoliinilla (Ronilan) 1—7 vuorokautta ennen sadonkorjuuta. Porkkanat säilytettiin kylmävarastossa +1 °C:n lämpötilassa huhtikuulle, jolloin niistä määritettiin tautisuudet. Sadonkorjuun yhteydessä otettiin lisäksi näytteitä jäämämäärityksiin.

Porkkanan naattien ruiskutus ennen sadonkorjuuta vähensi tai jopa esti kokonaan harmaahomeen ja pahkahomeen tuhot. Paras torjunta-aika oli vuorokausi ennen sadonkorjuuta. Sadonkorjuuhetkellä oli porkkanoissa torjunta-ainejäämiä, mutta määrät olivat kaikissa tapauksissa alle kymmenesosa suositelluista enimmäismääristä. Jäämät olivat pienimmät, kun käsittely tehtiin naateille vuorokausi ennen sadonkorjuuta. Tästä torjuntamentelmästä ei ole kirjallisuudessakaan aikaisemmin mainintaa. Porkkanan naattien fungisidikäsittelyille varastotautien torjumiseksi ei ole vielä virallista hyväksyntää.

ANNALES AGRICULTURAE FENNIAE, VOL. 24: 97—100 (1985)
Seria ANIMALIA NOCENTIA N. 119 — Sarja TUHOELÄIMET n:o 119

Research note

PESTS OF CULTIVATED PLANTS IN FINLAND IN 1984

MARTTI MARKKULA

MARKKULA, M. 1985. **Pests of cultivated plants in Finland in 1984.** Ann. Agric. Fenn. 24: 97—100. (Agric. Res. Centre, Dept. Pest Inv. SF-31600 Jokioinen, Finland.)

The damage caused by about fifty insects and other animal pests on cereals, forage plants, root crops, vegetables, rape, sugar beet, pea, apple, berries and other cultivated plants in Finland in 1984 is reported from the results of questionnaire surveys.

The effective temperature sum of the growth period was slightly larger than on average, and rainfall during the growth period heavier than normal.

The answers to inquiries showed that average abundance of all pests, in terms of a 1—5 value scale, was 2,6 or the same as during the ten-year period 1965—1974.

Lygus rugulipennis, which has been scarce for many years, attacked heavily sugar beet cultivations. *Meligethes aeneus* continued to occur in large numbers and damaged rape flowers as well as cauliflower. *Sitodiplosis mosellana* larvae were unexpectedly found in wheat.

Trioza apicalis caused more damage than usual in the South and Middle Finland. Its abundance seems to be rising.

Many pests especially aphids, were less abundant than normal.

Index words: plant pests, severity of damage, frequency of damage, Finland, *Lygus rugulipennis, Meligethes aeneus, Sitodiplosis mosellana, Trioza apicalis.*

The survey is based on replies to inquiries sent to the advisers at Agricultural Advisory Centres. The network of 200 advisers covers all 461 municipalities. Four inquiries were sent during the growing season, and replies were received as follows:

	Replies	%	Municipalities	%
Spring inquiry	133	62	166	36
First summer inquiry	107	51	143	31
Second summer inquiry	98	46	124	27
Autumn inquiry	98	46	122	26

Each inquiry requested an estimate of the severity and frequency of damage caused by the insects and other pest animals specified in the questionnaire. A scale of 0—10 was used to estimate the severity of damage, and the frequency of damage was estimated as the percentage of cultivations in which damage had occurred in each observation area.

In the autumn inquiry the advisers were also asked to make a general estimate of the abundance of each pest throughout the growing season. A scale of 1—5 was employed for this: very sparse, sparse, normal, abundant, very abundant. The same inquiry requested an estimate of the percentage of apples damaged

Table 1. Results of questionnaires. Severity of damage estimated according to a scale of 0—10. Frequency of damage calculated as the percentage of crops in which damage was observed.

	Number of observations 1984	Severity of damage 1984	Severity of damage 1965—74	Frequency of damage 1984	Frequency of damage 1965—74
CEREALS					
Sitobion avenae (F.)	66	1,0	1,4	26	22
Rhopalosiphum padi (L.)	66	0,9	1,2	18	18
Oscinella frit (L.)	86	0,5	1,0	6	13
Elateridae	43	0,5	1,1	5	15
Phyllotreta vittula (Redtb.)	84	0,5	1,0	9	18
FORAGE PLANTS					
Nanna spp.	55	1,0	1,5	25	28
Apion spp.	29	0,5	1,0	18	16
RAPE AND TURNIP RAPE					
Meligethes aeneus (F.)	53	2,4	1,8	64	40
Phyllotreta spp.	52	1,3		39	
Ceutorhynchus assimilis (Payk.)	23	0,4		13	
Dasineura brassicae (Winn.)	20	0,3		6	
SUGAR BEET					
Lygus rugulipennis Popp.	42	3,1	1,9	58	43
Chaetocnema concinna (March.)	53	1,9	1,7	54	40
Pegomya betae (Curt.)	71	1,6	1,8	38	48
Aclypea opaca (L.)	28	1,3	1,4	32	33
PEA					
Cydia nigricana (F.)	30	1,7	1,9	26	37
ROOT CROPS AND VEGETABLES					
Trioza apicalis (Först.)	61	2,1	1,3	36	21
Phyllotreta spp. on crucifers	77	2,0	2,0	36	38
Delia radicum (L.) and *D. floralis* (Fall.)	90	1,7	2,0	28	28
Pieris brassicae (L.) etc.	37	1,6	1,7	25	29
Plutella xylostella (L.)	41	1,6	1,6	25	21
Delia antiqua (Mg.)	43	1,4	1,9	21	21
Psila rosae (F.)	39	0,9	0,8	18	10
Phaedon cochlearie (F.)	29	0,7	1,1	16	19
Brevicoryne brassicae (L.)	26	0,6	0,8	6	14
APPLES					
Lepus europaeus Pallas and *L. timidus* L.	61	2,5	1,6	35	15
Argyresthia conjugella Zell.	43	2,5	3,4	38	46
Cydia pomonella (L.)	40	2,2	2,5	36	42
Panonychus ulmi (Koch.)	39	1,1	1,3	17	21
Aphis pomi (Deg.)	23	1,0	1,5	25	24
Yponomeuta padellus malinellus Zell.	25	0,8	1,6	17	23
Microtus agrestis (L.) stem damages	37	0,8	1,1	4	8
Psylla mali (Schmidbg.)	31	0,7	0,9	13	13
Arvicola terrestris (L.) root damages	34	0,7	0,5	3	4
Xyleborus dispar (F.)	27	0,3	0,5	3	4
BERRIES					
Cecidophyopsis ribis (Westw.)	77	1,9	2,2	28	30
Lampronia capitella Cl.	61	1,8	1,9	24	22
Nematus ribesii (Scop.) and *Pristiphora pallipes* Lep.	45	1,8	1,7	19	16
Tarsonemus pallidus Bks.	50	1,8	2,0	21	28
Byturus tomentosus (Deg.)	34	1,6	1,7	26	29
Anthonomus rubi (Hbst.)	40	1,5	1,6	27	26
Pachynematus pumilio Knw.	49	1,4	1,3	21	21
Aphididae on *Ribes* spp.	41	1,1	1,8	17	26
Tetranychus urticae (Koch.)	31	1,1	1,3	16	21
Zophodia convolutella (Hbn.)	28	0,4	0,9	5	12
PESTS ON SEVERAL PLANTS					
Deroceras agreste (L.) etc.	31	1,5	1,3	22	24
Hydraecia micacea (Esp.)	32	1,2	1,2	35	21

by *Argyresthia conjugella* and *Cydia pomonella* and of pea pods damaged by *Cydia nigricana*.

Altogether 215 municipalities were reported on by the advisers.

The termic growth period started normally or slightly earlier than normal. May was markedly warmer than normal everywhere in the country, but the months from June to September cooler than on average. Precipitation during the growth period was larger than normal in almost all parts of the country.

The average abundance of pests, in terms of the 1—5 scale, during the entire growing season was 2,6, i.e. the same as the average during the ten-year period 1965—1974.

Cereal fields had no serious pest problems. *Rhopalosiphon padi* and *Sitobion avenae* occurred in notably smaller numbers than during 1965—1974 (Table 1).

The previous summer unidentified damage on wheat was observed in Anjalankoski, southern Finland. In 1984 the pest was identified: it was wheat midge, *Sitodiplosis mosellana* Geh. (HELENIUS et al. 1984). Earlier this species has been found only a few times in Finland (VAPPULA 1962, p. 25). In summer 1983 the damages seemed locally very severe.

Meligethes aeneus continued to occur in large numbers. Damages were clearly larger than the ten-year average. The beetles reduced the seed yield of rape, but during the last few years they have also caused novel damages in cauliflower.

After an intermittent period of several years the bug *Lygus rugulipennis* attacked sugar beet cultivations again in large numbers and forced the farmers to additional pesticide sprayings. *L. rugulipennis* caused damages in about 20 plant species.

The populations of *Trioza apicalis* continued to increase. The value for the severity of damage was clearly greater than the previous year or in 1965—74. *T. apicalis* was so abundant and wide-spread that chemical control was necessary in almost all carrot cultivations. Cultural methods of control did not help (cf. MARKKULA 1984).

In apple orchards the pest situation was normal. During the winter hares damages unprotected or purely managed orchards more than on average. *Argyresthia conjugella* and *Cydia pomonella* caused remarkably more damages compared to the very low population levels during the previous summer. The advisers' estimates of damage to apples indicated the following:

	percentage of apples damaged			replies
	1984	1983	1965—74	
Argyresthia conjugella	35	6	31	20
Cydia pomonella	32	6	22	21

In berry plants pest damages were small. Especially aphids were low in numbers.

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SELOSTUS

Viljelykasvien tuhoeläimet 1984

MARTTI MARKKULA

Maatalouden tutkimuskeskus

Maatalouskeskusten piiriagrologien arvioiden mukaan tuholaisten runsautta voidaan pitää melkolailla normaalina. Tuholaisten runsautta kuvaava luku oli 2,6 eli sama kuin vertailukautena 1965—1974.

Peltolude hyökkäsi monien vuosien niukan esiintymisen jälkeen suurin joukoin sokerijuurikasviljelyksille. Rapsikuoriaisen runsaan esiintymisen kausi jatkui. Kuoriainen alensi rypsin siemensatoa ja vioitti myös kukkakaaleja.

Vehnässä havaittiin yllättäen runsaasti tähkäsääsken (*Sitodiplosis mosellana*) toukkia Anjalankoskella. Sääsken aiheuttamista vioituksista on aiemmin vain muutamia havaintoja. Porkkanakemppi esiintyi runsaampana kuin moniin vuosiin. Sipulin ja porkkanan viljely vuororivein ei vähentänyt kempin tuhoja, vaikka menettelyä on neuvottu tehokkaana porkkanakempin torjuntakeinona.

Monia tuholaisia, etenkin lehtikirvoja, oli poikkeuksellisen niukasti.

Katsaus on julkaistu laajempana Maaseudun Tulevaisuuden liitteessä Koetoiminta ja Käytäntö 31.3.1985.

ANNALES AGRICULTURAE FENNIAE, VOL. 24: 101—102 (1985)
Seria PHYTOPATHOLOGIA N. 100 — Sarja KASVITAUDIT n:o 100

Research note

STRAWBERRY LATENT RING SPOT VIRUS IN ORNAMENTAL PLANTS IN FINLAND

KATRI BREMER

BREMER, K. 1985. **Strawberry latent ring spot virus in ornamental plants in Finland.** Ann. Agric. Fenn. 24: 101—102. (Agric. Res. Centre, Dept. Plat Pathol., SF-31600 Jokioinen, Finland.)

The strawberry latent ring spot virus was found first time in Finland. The virus infected ornamental plants of species *Astible x arendsii, Paeonia officinalis, Phlox paniculata* and *P. subulata.* Raspberry ring spot virus occurred in the same plants, too.

Index words: *Astible* x *arendsii,* ornamental plants, *Paeonia officinalis, Phlox paniculata, P. subulata,* raspberry ring spot virus, strawberry latent ring spot virus.

Samples of *Astible* x *arendsii, Paeonia officinalis, Phlox paniculata* and *P. subulata* were tested for virus diseases in order to find healthy propagation material. Test were carried out by using test plants and antisera.

Sap transmission was done from young leaves of perennial plants on to *Chenopodium quinoa* and *Nicotiana tabacum,* ovs Samsun and White burley. Serological tests were carried out by using sap pressed from leaves of test plants in double diffusion tests. Only two antisera were used viz. antiserum against strawberry latent ring spot virus (supplied by Dr J. I. Cooper, Oxford) and antiserum against raspberry ring spot virus (supplied by Dr A. Thomson, Lyngby). According to the symptoms in test plants other NEPO-viruses occurred, too.

14 samples of 21 tested samples of *A. arendsii* were infected. Strawberry latent ring spot virus and raspberry ring spot virus occurred together and separately according to the serological tests.

19 of 37 tested *P. officinalis* samples were infected. Raspberry ring spot virus was more common than the strawberry berry latent ring spot virus.

19 samples of tested 21 samples of *P. paniculata* were infected. Raspberry ring spot and strawberry latent ring spot viruses occurred together and separately.

All tested 18 samples of *P. subulata* were infected with both viruses.

Symptoms of each virus cannot be described because of the mixed infections.

Infected *A. arendsii* plants had narrow small leaves, which curled downwards. Sometimes faint yellow flecks occurred on leaves. The plants were dwarfed.

Infected *P. officinalis* plants were dwarfed. Yellow mottling appeared often on their leaves.

Infected *P. subulata* plants were stunted and they had small, crinkled leaves. Leaves had light yellow flecks, they often turned yellow and withered. The shoots died, too.

This is the first report of strawberry latent ring spot virus in Finland and as far as the writer knows *A. arendsii* and *P. officinalis* are new hosts to the strawberry latent ring spot virus.

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SELOSTUS

Mansikan latentti rengaslaikkuvirus todettu Suomessa koristekasveilla

KATRI BREMER

Maatalouden tutkimuskeskus

Mansikan latentin rengaslaikkuviruksen todettiin esiintyvän Suomessa. Se tunnistettiin testikasvien ja serologisten testien avulla. Virus esiintyi jaloangervossa, tarhapionissa, sammal- ja syysleimussa. Jaloangervo ja tarhapioni ovat viruksen uusia isäntäkasveja.

Virustautiset kasvit olivat pienikokoisia, ja niiden lehdet keltakirjavia ja kurttuisia. Sammalleimun lehdet ja versot kellastuivat ja kuolivat.

Mansikan latentin rengaslaikkuviruksen ohella sairaista kasveista tunnistettiin serologisesti myös vadelman rengaslaikkuvirus. Testikasveissa ilmenneiden oireiden mukaan myös muita maalevintäisiä viruksia esiintyi samoissa kasveissa. Siten edellä kuvatut oireet olivat sekainfektioiden aiheuttamia.

ANNALES AGRICULTURAE FENNIAE, VOL. 24: 103—105 (1985)
Seria AGRICULTURA N. 73 — Sarja PELTOVILJELY n:o 73

Research note

PHYTIC ACID CONTENT OF SOME OAT VARIETIES AND ITS CORRELATION WITH CHEMICAL AND AGRONOMICAL CHARACTERS

MARKETTA SAASTAMOINEN and TIINA HEINONEN

SAASTAMOINEN, M. & HEINONEN, T. 1985. **Phytic acid content of some oat varieties and its correlation with chemical and agronomical characters.** Ann. Agric. Fenn. 24: 103—105. (Agric. Res. Centre, Dept. Plant Breed., SF-31600 Jokioinen, Finland.)

The phytic acid content of nine commercial oat varieties and the line Jo 1033 were analysed. Phytic acid content showed a high positive correlation with the mean protein content ($r = 0{,}902^{***}$) of these commercial varieties. This is very well explained by the previous research results that the phytic acid is located in the protein bodies (aleurone grains) of the scutellar parenchyma and the aleurone layer of the oat grain.

Index words: phytic acid, oats, protein content.

Phytic acid, the hexaphosphate of myoinositol is a major storage form of phosphorus (P) in oats and other cereal grains. Phytic acid is found in the seeds of many cereals, oil crops and legumes, e.g. barley, beans, maize, cotton, oats, peanuts, peas, rape, rice, sesame, soya, sunflower and wheat (MAGA 1982). Phytic acid is an important phosphorus source for ruminants, but in humans and monogastric animals it may cause serious mineral deficiencies in the diet (ROBERTS and LOEWUS 1968, TURNLUND et al. 1984). Phytic acid may cause deficiencies of Ca, Zn, and possibly Fe by the chelating affinity between the phosphorus of the phytic acid and the minerals.

Differences in the phytic acid content between oat varieties have been studied very little. At the Department of Plant Breeding of the Agricultural Research Centre the varieties and breeding lines in experimental trials were studied in respect of their phytic acid content. Four experimental trials were established in 1982 and the phytic acid was analysed in 1983 according to MILLER et al. (1980). All chemical analyses were made from whole milled grain including hull and bran. Some oat varieties and lines were included in all four experimental trials, while some varieties were only in one trial. The mean values of the phytic acid contents and some other characters of these oat

Table 1. Means of phytic acid content and some chemical and agronomical characters of some oat varieties in relation to the standard variety 'Puhti' grown at Jokioinen in Finland in 1982.

Variety	Number of trials	Growing time days	Grain yield kg/ha	Protein %	Hull %	1000 grain weight g	Phytic acid %
Puhti, standard	4	96	6163 (=100)	14,7	23,0	38,5	0,693
Ryhti	4	+5	90	−0,2	+1,7	+0,6	−0,001
Nasta	4	−1	82	+0,9	+2,1	−4,4	+0,041
Veli	4	−2	86	+0,5	+2,8	−2,6	+0,048
Pol	4	−9	71	+1,5	+4,7	−7,9	+0,069
Titus	2	−3	85	+0,6	+3,8	−0,5	+0,086
Jo 1033	2	−4	92	+2,1	+2,2	−4,2	+0,114
Svea	1	+2	95	−0,4	+3,1	−3,0	−0,035
Hankkija's Vouti	1	+5	92	−0,3	+1,9	−0,5	+0,005
Kalott	1	−10	81	+1,0	+5,8	−1,9	+0,062
Caesar, hull-less	1	±0	48	+8,2	−23,0	−8,2	+0,425
Correlation coefficient, r, between phytic acid content and other characters calculated excluding Caesar		−0,697*	−0,510	0,902***	0,422	−0.410	

Significance: *$p < 0,05$; ***$p < 0,001$

varieties are given in Table 1. 'Caesar', the hull-less oat variety, has a much higher protein and phytic acid content than the other oat varieties. The high protein and phytic acid content of the 'Caesar' variety is, of course, caused by its hull-less character. There are differences in phytic acid content between the normal oat varieties. There is a low phytic acid content in the late and middle late varieties 'Puhti', 'Ryhti', 'Svea' and 'Hankkija's Vouti'. Early varieties have a higher phytic acid content and higher protein content (Table 1). The differences in phytic acid content were not statistically significant between the oat varieties when tested by the paired t-statistics, as the number of trials was not high. ASHTON and WILLIAMS (1958) have not found significant differences in the phytic acid content of oat varieties either, but MILLER et al. (1980) found small differences between four oat varieties grown in four years at three locations.

Correlation coefficients were calculated between the phytic acid content and other agronomical and chemical characters of the oat varieties. Calculations were made excluding 'Caesar', the hull-less oat variety. The highest positive correlation was obtained between the protein content and the phytic acid content, $r = 0,902^{***}$ ($n = 10$) (Table 1). Phytic acid is located in the protein bodies (aleurone grains) of the scutellar parenchyma and the aleurone layer of the oat grain (FULCHER et al. 1981) which largely explains the high positive correlation between the protein content and the phytic acid content. It also explains the negative correlation between the phytic acid content and grain size, because in small grains the scutellar parenchyma and the aleurone layer constitute relatively greater parts of the grain than in large grains.

Significant negative correlation was found between the growing time and the phytic acid content, $r = -0,697^{*}$ ($n = 10$) (Table 1). This can be explained by the fact that early oat varieties have a high protein content, whereas the late varieties have a low one. Negative correlation between the phytic acid content and grain yield is caused by the unequal protein

content in late high yielding varieties and in early average yielding varieties. The late high yielding varieties usually have a lower protein content than the early average yielding varieties.

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SELOSTUS

Kauralajikkeiden fytiinihappopitoisuus ja sen korreloituminen muiden ominaisuuksien kanssa

MARKETTA SAASTAMOINEN ja TIINA HEINONEN

Maatalouden tutkimuskeskus

Fytiinihappoa, myoinositolin heksafosfaattia, on monien vilja-, öljy- ja palkokasvien siemenissä. "Fytiinihappokasveja" ovat mm. kaura, ohra, maissi, puuvilla, herne, rapsi, riisi, seesam, soija, auringonkukka, vehnä ja maapähkinä.

Fytiinihappo sisältää runsaasti fosforia. Märehtijöille fytiinihappo on tärkeä fosforin lähde, mutta yksimahaisille eläimille, lähinnä sioille ja kanoille, sekä ihmiselle fytiinihappo saattaa aiheuttaa kivennäisaineiden, kalsiumin, raudan ja sinkin puutetta kelatoitumalla näiden kivennäisaineiden kanssa sulamattomaan muotoon.

Maatalouden tutkimuskeskuksessa kasvinjalostusosastolla suoritettiin fytiinihappomäärityksiä lajikekokeissa olleista kauralajikkeista ja -linjoista. Fytiinihappoanalyysejä suoritettiin vuoden 1982 sadosta. Eri kauralajikkeiden välillä esiintyi eroja fytiinihappopitoisuuden määrässä. Kauralajikkeiden keskimääräinen fytiinihappopitoisuus korreloi positiivisesti proteiinipitoisuuden kanssa. Niissä lajikkeissa, joissa on korkea proteiinipitoisuus, on yleensä myös korkea fytiinihappopitoisuus. Märehtijöille tämä on etu. Yksimahaisten eläinten kannalta tulos on kuitenkin epäedullinen.

ANNALES AGRICULTURAE FENNIAE, VOL. 24: 107—114 (1985)
Seria ANIMALIA DOMESTICA N. 71 — Sarja KOTIELÄIMET n:o 71

DIGESTIBILITY OF NITROGEN AND AMINO ACIDS OF SOME DRY FEEDSTUFFS FOR MINK

TUOMO KIISKINEN, LEA HUIDA, BARBARA PASTUSZEWSKA and HANS BERG

KIISKINEN, T., HUIDA, L., PASTUSZEWSKA, B. & BERG, H. 1985. **Digestibility of nitrogen and amino acids of some dry feedstuffs for mink.** Ann. Agric. Fenn. 24: 107—114. (Agric. Res. Centre, Inst. Anim. Husb., SF-31600 Jokioinen, Finland.)

The apparent (ADN) and true (TDN) digestibilies of total nitrogen and amino acids (ADAA, TDAA) were studied in herring meal, meat meal, poultry by-product meal (PBM), soybean meal, potato protein (Protamyl), wheat gluten (WG) and Pekilo single cell product using black male minks and the difference method of total excreta collection. Metabolic faecal nitrogen and amino acids were determined by feeding a proteinfree diet to one group.

ADN and TDN of the protein sources in the above mentioned order were: 73,9, 79,7, 77,9, 83,5, 50,4, 55,1, 78,6, 84,5, 80,9, 86,9, 89,3, 96,0, 78,1, 83,4 % respectively. The values of PBM and WG differed significantly ($P < 0,05$) from the others. TDN was an average of 5,7 percentage units higher than ADN.

In general the mean digestibility of the individual amino acids was clearly higher than the corresponding N digestibility. The average ADAA ranged from 67 (PBM) to 90 % (Pekilo) and TDAA from 73 (PBM) to 97 % (WG). Significant differences in the values of individual amino acids were found between the protein sources. The internal variation of the values among the individual amino acids was great especially in PBM, in which TDAA ranged from 44 (histidine) to 93 % (threonine). It can be concluded that the digestibility determinations of amino acids are reasonable and useful.

Index words: apparent and true digestibility, protein sources, amino acids, mink.

INTRODUCTION

Under Finnish conditions there are occasionally shortage of fresh feed of animal origin especially that of good quality. Therefore dried animal products like fish meals and meat meals have been used as complementary protein sources, and alternative protein sources like vegetable and single cell proteins have been tested and also used in small dietary concentrations. Digestibility of protein in these feedstuffs has been intensively investigated during the last ten years, especially in the Scandinavian countries but knowledge of the digestible amino acids in these products is relatively slight.

The Norwegian and Danish studies have shown that the true digestibility of amino acids in meat and bone meals is relatively low (59—73 %) and the differences in digestibility between the individual amino acids are great (SKREDE 1979 a, 1980, MEJBORN 1983 a). On the other hand the values of fish meals were considerably higher (86—91 %) and the variation smaller than that of meat and bone meals (SKREDE 1980). MEJBORN (1983 b) reported very high true digestibility values: an average of 95 % (86—100 %) for the amino acids of a soyprotein concentrate.

The present study was performed in order to obtain more information about the digestibility of some dry protein sources, especially concerning their amino acids.

MATERIAL AND METHODS

Animals and housing

Twenty four dark male minks aged 27 weeks were placed into individual metal cages especially designed for digestibility experiments on this animal species. The minks were arranged in groups of six animals; an attempt was made to equalize the body weight distribution of the groups. The trial was performed in a ventilated room in which the temperature varied between 12 and 15 °C. The kits had a free access to water.

Protein sources, diets and feeding

The following dry protein sources were investigated: herring meal (HM), meat meal (MM), poultry by-product meal (PBM), soybean meal (SBM), wheat gluten meal (WG), potato protein concentrate (Protamyl) and Pekilo single cell product. The animal products were imported from Denmark and the Protamyl from Holland. Wheat gluten meal and Pekilo (a microfungus *Paecilomyces varioti*) were produced by the Finnish wheat starch and sulphite cellulose industries, respectively. The proximate and amino acid composition of the test ingredients are shown in Table 1.

The protein feedstuffs were used as sole sources of protein in the diets, including cooked wheat starch and soybean oil as energy sources. One group was fed a protein-free (PF) diet (Table 2) to determine metabolic faecal nitrogen (MFN) and amino acids (MFAA). The protein sources in this diet partly replaced wheat starch and soybean oil so that the calculated apparent digestible protein in the diets was 7,0—7,3 g/100 kcal ME. The content of protein sources varied from 38,5 (WG) to 63 % (SBM) and the protein concentration of the diets according to the analysis was 31,1—37,8 % (Table 3). Before feeding water was added to the diets in the ratio 1,5—2:1 to make a consistent porridge like mass. Feeding was performed twice a day, in the morning and in the afternoon, and the daily ration (wet feed) varied between 150 and 250 g per mink according to the feed intake during the adaptation period. The daily rations were made and weighed one day before feeding and stored in a refrigerator (+4 °C).

Experimental procedures

The digestibility was determined by total faeces collection. The experiment consisted of two parts, including a three-day adaptation period and a four-day collection period each. PF, SBM, Protamyl and HM diets were given during the first part of the trial and the other diets were

Table 1. Proximate and amino acid analysis of the protein sources.

	Herring meal (HM)	Meat meal (MM)	Poultry by-product meal (PBM)	Soybean meal (SBM)	Prota-myl	Wheat gluten (WG)	Pekilo
Dry matter %	92,7	95,7	87,2	88,9	89,5	92,7	90,7
In DM %							
crude protein	74,5	75,7	77,8	53,8	86,2	83,4	61,4
crude fat	11,1	10,0	2,8	1,3	0,8	0,9	2,4
carbohydrates	1,3	4,6	4,6	38,6	11,8	15,2	29,6
ash	13,1	9,7	14,8	6,3	1,2	0,5	6,6
g/16 g N							
methionine	2,3	0,9	0,8	1,4	2,0	1,3	0,8
lysine	6,3	4,2	3,9	5,9	7,9	1,6	6,6
arginine	5,6	6,0	7,3	6,8	5,6	3,5	6,3
histidine	2,0	1,5	1,3	2,0	1,7	2,0	2,2
isoleucine	4,1	1,6	3,2	4,0	6,2	3,3	4,1
leucine	7,2	3,9	7,2	7,3	11,1	7,0	6,9
phenylalan.	4,3	2,4	3,9	5,2	6,9	5,6	4,1
tyrosine	2,8	1,8	3,3	4,2	5,8	3,5	3,4
threonine	4,4	2,2	4,2	4,1	6,6	2,6	4,3
valine	5,0	2,8	5,0	4,7	7,5	3,7	4,9
alanine	6,3	6,8	5,9	4,5	5,3	2,5	6,2
asp. acid	8,5	6,1	6,9	10,4	13,1	3,3	9,3
glycine	5,7	12,9	8,4	4,3	5,3	3,4	4,6
glut. acid	11,6	10,7	12,6	15,3	11,2	36,0	14,3
proline	4,0	9,2	7,5	5,4	5,8	13,0	4,0
serine	4,2	3,4	7,2	5,4	5,6	4,7	4,2

Table 2. Composition of the protein-free (PF) diet.

Cooked wheat starch	61,4	%	Vitamin B_2	5	mg
Soybean oil	27,2	"	Vitamin B_6	1,5	"
Silicate (Celite 545)	6,6	"	Vitamin B_{12}	0,02	"
Ca HPO_4	4,0	"	Niacin	25	"
Na Cl	0,3	"	Folic acid	0,4	"
Mineral-vitamin premix	0,5	"	Fe	20	"
Supplies per kg:			Mn	50	"
Vitamin A	20000	I.U.	Zn	45	"
Vitamin D_3	2500	"	Cu	4	"
Vitamin E	30	mg	Co	0,5	"
Vitamin K_3	1,5	"	I	0,5	"
			Se	0,5	"

Table 3. Protein content of the diets and average daily intake of dry matter (DM), protein (CP) and metabolizable energy (ME) and change in body weight during the collection period.

Diet	PF	HM	MM	PBM	SBM	Protamyl	WG	Pekilo
N	3	6	3	5	5	5	5	6
Analyzed dietary CP % in DM	0,8	32,2	33,6	37,8	32,3	31,1	31,8	35,6
Average intake/mink/day								
DM g	26,5	59,1	36,3	34,1	45,1	30,8	35,7	37,9
CP g	0,2	19,0	12,2	12,9	14,6	9,6	11,4	13,5
ME kcal[1)]	109	207	137	108	171	111	130	140
Change in weight g	−96	+93	−132	−144	+28	−15	−129	−116

[1)] Calculated by means of the factors 4,5, 9,3 and 4,1 kcal/g for digested protein, fat and carbohydrates respectively.

given during the second part. After the first part of the experiment the kits were reallocated between the groups. The animals were weighed before and after each part of the experiment. Faeces were collected once a day and stored between the collections in plastic boxes with tightly fitting lids at −20 °C. Daily feed remains were collected individually, weighed and air-dried for correction of feed intake.

Protein quality of WG, Protamyl and SBM was investigated on growing rats at the Institute of Animal Physiology and Nutrition of Polish Academy of Sciences by the THOMAS-MITCHELL method using 8 rats per group.

Analytical methods and calculation

Proximate analysis of the protein sources was performed according to the standard methods used in the Department of Animal Husbandry of the Agricultural Research Centre. The nitrogen content of the faeces was determined from thawed homogenized samples and the other determinations (ash, amino acids) were made from the dried samples (60 °C, 16 hours). Amino acids were determined with a gas chromatograph (Hewlett Packard 1570) after hydrolysis in 6 N HCL saturated with nitrogen gas (110 °C for 20 hours). Tryptophane was not determined and the cystine values were too low to be accepted. Amino acid analysis was performed on the faeces of three animals per group. The animals were chosen according to the digestibility of nitrogen to represent the average value of the group.

In the calculation of TDAA the equation presented by GLEM—HANSEN (1982) was used.

The results were statistically evaluated using analysis of variance. The differences between the protein sources were tested by the t-test.

RESULTS AND DISCUSSION

With the exception of the HM diet feed intake was very low, clearly because of poor acceptability of the diets (Table 3.). This concerned the PF diet in particular and for this reason three minks of this group, three of the MM group and one each of the PBM, SBM, Protamyl and WG groups should be excluded from the experiment. However, the average dry matter consumption (26,5 g/day) of three minks in the PF group was nearly exactly the same as that of six minks in a study by SKREDE (1979 a) in which the PF diet had approximately the same composition as in the present study. The protein consumption also varied considerably, ranging from 9,6 (Protamyl) to 19,0 g/day (HM). The daily ME intake was only 111—207 kcal and therefore the kits of most groups lost weight during the collection period (Table 3).

The ADN of herring meal (73,9 %) was surprisingly low (Table 4) because this value for fish meal used in mink diets is usually more than 80 % (KIISKINEN and MÄKELÄ 1976, SKREDE 1977, 1979 b, GLEM—HANSEN and JØRGENSEN 1978). The colour of the HM did

Table 4. Digestibility of organic matter and nitrogen in the experimental diets (± SD).

	Apparent digestibility		True digestibility	
Diet	org.m.	nitrogen (ADN)	nitrogen (TDN)	TDN-ADN
PF	80,6 ± 1,2			
HM	84,2 ± 2,4^{b}	73,9 ± 2,4^{b}	79,7 ± 2,4^{b}	5,8
MM	84,3 ± 0,6^{b}	77,9 ± 1,2^{c}	83,5 ± 1,2^{c}	5,6
PBM	69,6 ± 1,3^{a}	50,4 ± 1,7^{a}	55,1 ± 1,7^{a}	4,7
SBM	68,4 ± 1,0^{a}	78,6 ± 2,7^{c}	84,5 ± 2,7^{c}	5,9
Protamyl	84,7 ± 1,8^{b}	80,9 ± 3,9^{c}	86,9 ± 4,0^{c}	6,0
WG	84,0 ± 2,2^{b}	89,3 ± 2,1^{d}	96,0 ± 1,7^{d}	6,7
Pekilo	70,7 ± 1,4^{a}	78,1 ± 1,4^{c}	83,4 ± 1,4^{c}	5,3
				$\bar{X}$ 5,7
F-value	90,3***	93,0***	102,8***	

a—d Means with a different superscript letter in the same column are significantly different ($P < 0,05$)

not reveal any overheating of the product. The ADN of HM was significantly lower ($P < 0,05$) than that of the other protein sources except PBM and SBM.

ADN of meat meal was 77,9 %, about the same as GLEM—HANSEN and JØRGENSEN (1978) presented for a product with a higher ash content. The amino acid composition of MM points to a high collagen (bone) protein content in spite of its low ash content (Table 1). The apparent digestibility of PBM was only 50,4 %, significantly lower ($P < 0,05$) than that of the other products. It is clearly lower than the values (63 and 59 %) presented by GLEM—HANSEN and JØRGENSEN (1975, 1978). Apparently the sample investigated in this study contained many feathers because its protein concentration was relatively high and the fat content low (Table 1). Also the amino acid composition of PBM supports the above mentioned supposition.

The ADN of soybean protein (78,6 %) agrees with the earlier studies (RIMESLÅTTEN 1974, ALDÉN and JOHANSSON 1975, JØRGENSEN and GLEM—HANSEN 1975, KIISKINEN and MÄKELÄ 1975, SKREDE 1977). The digestibility of potato protein is relatively high (80,9 %) but it is lower than the values of 88—95 % presented by GLEM—HANSEN (1979). Wheat gluten was highly digested (89,3 %) but still greater ADN values of 94 % have been measured (KIISKINEN unpubl.). The ADN of Pekilo (78,1 %) is in agreement with the earlier results reported (KIISKINEN et al. 1980).

The metabolic faecal nitrogen determined using the PF diet was an average of 360 mg per 100 g consumed dry matter. Using the same method SKREDE (1979 a) obtained a mean value of 310 mg/100 g dm from six animals. The average MFN of three minks in the present study can be regarded as fairly available when calculating the TDN of the test ingredients. The TDN values were around six percentage units higher than their ADN values (Table 4). PBM had the lowest TDN 55,1 % ($P < 0,05$), and WG the highest 96,0 % ($P < 0,05$).

The values of metabolic faecal amino acids (mg/100 cons. d.m.) were as follows:

methionine	17	phenylalanine	75	glycine	88		
lysine	52	tyrosine	58	glut.acid	262		
arginine	72	threonine	181	proline	126		
histidine	29	valine	118	serine	104		
isoleucine	91	alanine	111				
leucine	129	asp. acid	133				

They were generally in fair agreement with the corresponding values reported by SKREDE (1979 a). In the case of isoleucine, leucine, valine and glutamic acid the MFAA in the present study was clearly higher than in the cited study. Excluding wheat gluten the average digestibility of amino acids was clearly higher than the corresponding value for nitrogen (Tables 4, 5 and 6). This is a typical trend in this kind of comparison and one has to take into consideration that their proportions have been ignored in the average values of digestible amino acids. Because the digestibility values of individual amino acids of WG are equal the difference compared with total nitrogen is small. The values of cystine and tryptophane were not included in the present study. In any case the above mentioned difference was great, especially in the case of PBM (ADN 50 %, ADAA 67 %).

Of course digestibility determinations using faecal analysis contain inaccuracies, which according to SKREDE (1980) tend to increase with decreasing digestibility. Large variation in the digestibility values of some individual amino acids can be found, especially as far as PBM is concerned (Table 5 and 6). Also non-protein nitrogen compounds can play some role in the digestibility of total nitrogen and this is very probable in the single cell proteins (nucleic acids). Apparently the relatively great difference between the DN and DAA values of Pekilo can at least partly be explained by the presence of nucleid acids, the concentration of which is around 20 % of the total nitrogen of

Table 5. Apparent digestibility of amino acids (ADAA, %) in the protein sources.

	HM		MM		PBM		SBM		Protamyl		WG		Pekilo		F-value
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	significance
Methionine	87^{b}	3,6	89^{b}	3,2	71^{a}	3,6	90^{b}	2,5	91^{b}	2,0	93^{b}	2,3	89^{b}	2,4	17,1***
Lysine	83^{c}	0,8	79^{b}	2,4	49^{a}	2,1	85^{c}	1,5	90^{de}	2,3	86^{cd}	3,7	93^{e}	2,5	90,5***
Arginine	88^{b}	0,9	92^{c}	1,7	69^{a}	8,0	91^{c}	0,5	90^{bc}	3,7	91^{c}	0,4	96^{d}	0,9	20,8***
Histidine	82^{b}	2,1	90^{c}	3,5	38^{a}	0,9	86^{bc}	1,1	90^{cd}	3,5	96^{d}	2,1	92^{cd}	4,3	92,6***
Isoleucine	85^{bc}	2,7	77^{b}	4,6	45^{a}	8,8	82^{b}	3,0	89^{c}	3,3	88^{c}	2,1	91^{c}	1,0	39,9***
Leucine	84^{b}	3,4	82^{b}	2,8	58^{a}	5,5	82^{b}	2,0	91^{c}	1,8	91^{c}	1,4	92^{c}	1,2	48,8***
Phenylalanine	85^{b}	2,0	85^{b}	1,6	63^{a}	3,8	84^{b}	1,8	91^{c}	1,6	94^{c}	0,8	91^{c}	2,2	69,4***
Tyrosine	81^{b}	3,6	84^{bc}	3,4	68^{a}	6,2	87^{c}	2,1	91^{d}	2,4	91^{d}	0,5	91^{d}	1,0	20,2***
Threonine	76^{bc}	2,0	68^{a}	3,4	82^{d}	0,2	70^{ab}	5,5	81^{cd}	4,3	71^{b}	2,6	83^{d}	2,6	9,5***
Valine	82^{b}	2,6	82^{b}	2,4	54^{a}	1,6	82^{b}	3,1	88^{cd}	3,0	87^{c}	0,8	90^{d}	1,0	85,2***
Alanine	86^{b}	2,3	85^{ab}	2,6	83^{ab}	0,2	80^{a}	3,1	86^{b}	2,5	82^{a}	1,3	93^{c}	1,2	10,6***
Aspartic acid	64^{b}	0,8	55^{a}	3,9	80^{c}	0,8	78^{c}	2,4	85^{d}	2,2	80^{c}	3,0	92^{e}	2,0	79,2***
Glutamic acid	77^{a}	1,5	78^{a}	0,2	81^{b}	0,4	77^{ab}	4,8	78^{ab}	3,7	96^{c}	0,8	84^{b}	5,4	13,7***
Glycine	76^{a}	2,1	80^{a}	1,4	86^{b}	0,2	76^{a}	3,7	84^{b}	2,3	88^{bc}	1,0	89^{c}	1,5	18,9***
Proline	79^{b}	1,7	84^{bc}	1,3	58^{a}	4,6	81^{b}	2,2	84^{bc}	2,3	96^{d}	0,4	88^{c}	2,1	76,3***
Serine	79^{a}	1,9	79^{a}	2,2	88^{b}	0,2	82^{a}	2,3	83^{ab}	3,8	89^{b}	1,2	89^{b}	2,4	10,6***
Mean	81	5,7	81	9,0	67	15,6	82	5,2	87	4,1	89	6,7	90	3,2	

a—e: Means not having the same superscript letter within a row are significantly different ($P < 0,05$)
*** : $P < 0,001$

Table 6. True digestibility of amino acids (TDAA, %) in the protein sources.

	HM		MM		PBM		SBM		Protamyl		WG		Pekilo		F-value
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	significance
Methionine	89^{b}	3,6	95^{bc}	3,2	78^{a}	3,6	94^{bc}	2,5	94^{bc}	2,0	97^{c}	2,3	95^{bc}	1,7	15,6***
Lysine	85^{bc}	0,8	82^{b}	2,4	52^{a}	2,1	87^{c}	1,5	92^{d}	2,3	96^{d}	3,7	95^{d}	2,1	99,6***
Arginine	92^{b}	0,9	96^{c}	1,7	72^{a}	7,9	94^{c}	0,5	94^{bc}	3,6	97^{c}	0,4	98^{c}	0,6	23,5***
Histidine	86^{b}	2,1	95^{c}	3,4	44^{a}	0,9	91^{bc}	1,2	96^{cd}	3,3	99^{d}	0,9	95^{cd}	3,7	105,5***
Isoleucine	92^{b}	2,6	94^{bc}	4,6	53^{a}	8,8	89^{b}	3,0	94^{bc}	3,2	98^{c}	0,7	97^{c}	0,5	41,7***
Leucine	89^{b}	3,4	92^{b}	2,3	63^{a}	5,5	88^{b}	1,9	95^{c}	1,7	98^{d}	0,6	97^{cd}	0,5	55,5***
Phenylalanine	90^{b}	2,0	94^{c}	1,6	68^{a}	3,8	89^{b}	1,6	94^{c}	1,5	98^{d}	0,8	95^{cd}	1,3	76,1***
Tyrosine	87^{b}	3,6	94^{bc}	3,5	73^{a}	6,2	91^{bc}	2,1	94^{c}	2,4	96^{c}	0,4	96^{c}	0,3	19,7***
Threonine	89^{ab}	2,0	92^{ab}	3,4	93^{ab}	0,3	84^{a}	5,5	90^{ab}	4,2	92^{ab}	2,2	94^{b}	1,9	3,38*
Valine	89^{b}	2,6	94^{c}	2,4	60^{a}	1,6	89^{b}	2,2	93^{b}	3,0	97^{c}	0,8	96^{c}	0,8	107,9***
Alanine	92^{a}	2,4	90^{a}	2,5	88^{a}	0,3	88^{a}	3,1	93^{a}	2,4	96^{b}	1,2	97^{b}	0,5	8,57***
Aspartic acid	69^{b}	0,7	61^{a}	3,9	85^{cd}	0,8	82^{c}	2,4	88^{d}	2,2	93^{e}	3,0	95^{e}	1,4	82,4***
Glutamic acid	84^{a}	1,5	85^{a}	0,2	86^{a}	0,3	82^{a}	4,6	85^{a}	3,5	98^{b}	0,8	89^{a}	4,5	9,72***
Glycine	81^{a}	2,1	82^{a}	1,4	88^{b}	0,3	83^{ab}	3,7	89^{b}	2,2	96^{c}	0,9	94^{c}	0,8	25,6***
Proline	89^{b}	1,7	88^{b}	1,3	62^{a}	4,6	88^{b}	2,1	92^{bc}	2,1	99^{d}	0,3	96^{c}	0,9	88,5***
Serine	87^{a}	1,9	88^{ab}	2,2	92^{b}	0,2	88^{ab}	2,3	89^{ab}	3,6	96^{c}	1,2	96^{c}	1,2	9,59***
Mean	87	5,7	89	8,7	73	15,2	88	3,7	92	2,8	97	2,0	95	2,1	

a—e: See Table 5.
* : $P < 0,05$
*** : $P < 0,001$

Pekilo (LEHTOMÄKI 1979). However, nucleic acid nitrogen is absorbed rather well (66—87 %) from the digestive tract of monogastric animals like hens (SHANNON and McNAB 1973, YAMAZAKI et al. 1977, GREIFE et al. 1981).

The TDAA values were also an average of six percentage units higher than the ADAA values (Table 5 and 6). Significant differences were ascertained between the protein sources in the digestibility of all individual amino acids investigated. Excluding threonine, all indispensable amino acids of PBM were digested significantly worse ($P < 0,05$) than the corresponding amino acids of the other feedstuffs. This also concerned proline in the dispensable amino acids. The average digestibility values of amino acids of the vegetable proteins and Pekilo were relatively high and

those of Protamyl, WG and Pekilo even better than the values of the animal proteins. The variation in the TDAA values was very narrow in WG, ranging from 92 (threonine) to 99 % (histidine, proline). On the other hand very large differences were discovered between the individual amino acids especially in PBM, in which histidine was digested at the lowest rate (44 %) and threonine best (93 %). The results of this study also disclose the need for digestibility studies of amino acids, especially if a feedstuff is relatively new, its orgin is indefinite or it has been processed.

The results of the bioassay performed on rats support the high digestibility values of the vegetable proteins obtained with minks (Table 7). The quality of vegetable protein is as a rule inadequate for monogastric animals. It is well known that methionine is the first limiting amino acid in soybean protein and this fact can be very clearly found also in potato protein, because the biological value (BV) of Protamyl increased from 75 to 95 and net protein utilization (NPU) from 70 to 90 as a result of the methionine supplementation. Wheat gluten is deficient in several amino acids, mainly lysine and methionine and therefore its BV was only 42 and NPU 39; in SBM these values were 67 and 58, respectively. The results of this trial also suggest that digestibility determinations of amino acids are justified because in several cases nitrogen digestibility is unsuitable for providing information about the digestibility of individual amino acids, which can vary within large limits. This information is needed in the determination of amino acid requirements and in feed formulation.

Table 7. The results of the evaluation of protein quality of Protamyl, wheat gluten and soybean meal in rats.

Protein	true digestibility	biological value	net protein utilization
Protamyl	93,7 ± 1,1	75,2 ± 2,3	70,4 ± 2,2
Protamyl + methionine[1)]	94,4 ± 1,1	95,0 ± 5,0	89,6 ± 4,6
WG	92,9 ± 2,0	41,6 ± 6,4	38,6 ± 5,8
SBM	86,1 ± 1,9	67,1 ± 5,1	57,7 ± 3,6

1) 2 g DL-methionine per 16 g N

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SELOSTUS

Eräiden kuivien rehujen typen ja aminohappojen sulavuus minkillä

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Ulkomaista alkuperää olevien sekä kotimaassa tuotettujen kuivien valkuaisrehujen sulavuutta tutkittiin urosminkeillä. Tutkimuksessa käytettiin ulosteiden kokonaiskeräilyyn perustuvaa erotusmenetelmää. Minkkien perusrehuna oli valkuaiseton, keitettyyn vehnäntärkkelykseen ja soijaöljyyn perustuva seos. Tutkimuksessa määritettiin ns. metabolinen typpi ja aminohapot ja sitä kautta valkuaisen (typen) ja aminohappojen todellinen sulavuus. Tutkittavina rehuina olivat sillijauho, lihajauho, siipikarjateurasjätejauho ja perunaproteiini, jotka olivat tuontirehuja, sekä maassamme uutettu soijajauho ja kotimaisen teollisuuden sivutuotteet, vehnägluteeni ja Pekilo-yksisoluvalkuainen.

Raakavalkuaisen näennäinen sulavuus oli 50,4—89,3 % ja todellinen 55,1—96,0 %. Heikommin suli siipikarjateurasjätejauho ja parhaiten vehnägluteeni. Erot olivat tilastollisesti merkittäviä. Kalajauhon sulavuus (73,9/79,7) oli yllättävän huono verrattuna kasvivalkuaisiin ja Pekiloon. Typen todellinen sulavuus oli keskimäärin noin 6 prosenttiyksikköä suurempi kuin näennäinen sulavuus.

Aminohappojen sulavuus oli kaikissa tutkituissa rehuissa, vehnägluteenia lukuun ottamatta, selvästi typen sulavuutta parempi. Aminohappojen näennäinen sulavuus vaihteli raaka-aineiden kesken 67—90 % ja todellinen sulavuus 73—97 %. Sulavuus oli huonoin siipikarjateurasjätteestä kuivatussa jauhossa, jossa yksittäisten aminohappojen sulavuuden välillä oli myös suuria eroja (44—93 %). Juuri tästä syystä aminohappojen sulavuuden määrittäminen on tarpeellista, koska raaka-aineiden alkuperä on joskus epämääräinen ja rehujen käsittely voi vaikuttaa aminohappojen käyttökelpoisuuteen.

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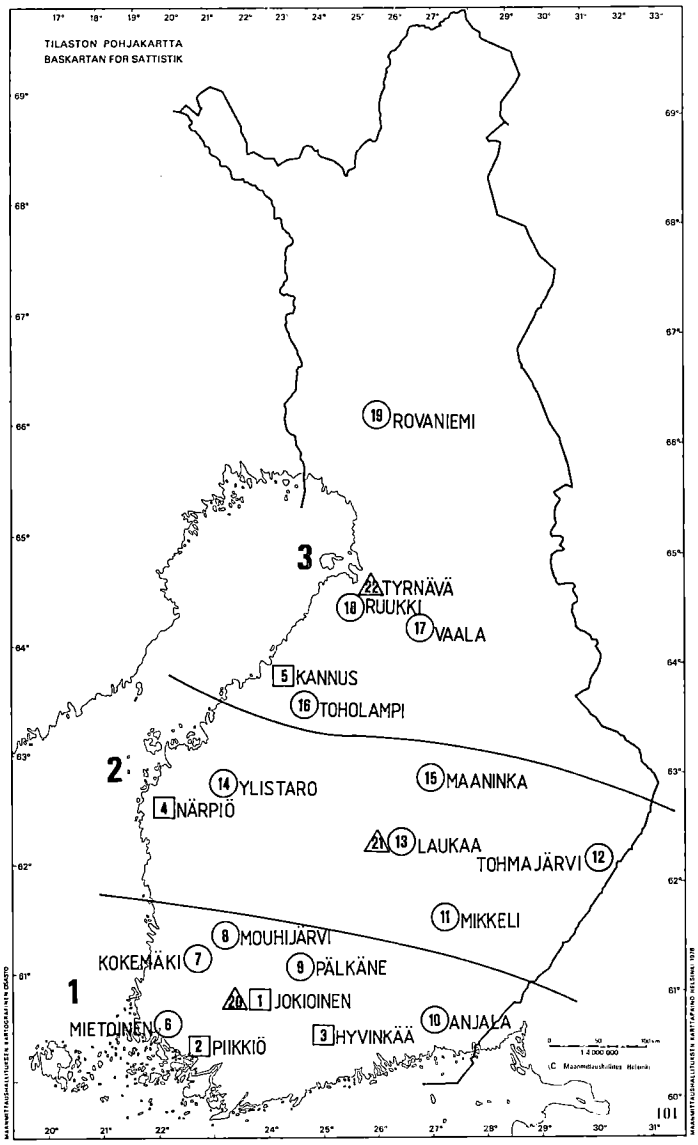

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