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ANNALES AGRICULTURAE FENNIAE, VOL. 24: 117—124 (1985)
Seria AGROGEOLOGIA ET-CHIMICA N. 131 — Sarja MAA JA LANNOITUS n:o 131

MINERAL NITROGEN RESERVES IN SOIL AND NITROGEN FERTILIZATION OF BARLEY

JOUKO SIPPOLA and TOIVO YLÄRANTA

SIPPOLA, J. and YLÄRANTA, T. 1985. **Mineral nitrogen reserves in soil and nitrogen fertilization of barley.** Ann. Agric. Fenn. 24: 117—124. (Agric. Res. Centre, Dept. Soil Sci., SF-31600 Jokioinen, Finland.)

With yearly applications of 80 kg/ha nitrogen, on different sites, in a soil layer of 0 to 100 cm, the mineral nitrogen in soil measured in spring, ranged from 15 to 78 kg/ha. The nitrogen application had no clear effect on the amount of mineral nitrogen in soil. The yearly variation in mineral nitrogen was small, an average of 6 kg/ha. The differences between experimental sites were more distinct. The mineral nitrogen in heavy clay soil ranged from 22—27 kg/ha, compared to the 45—78 kg/ha found in peat soil.

The heavy clay soil that contained low concentrations of mineral nitrogen at the time of sowing, gave the lowest yields of barley when no nitrogen fertilizer was added. The highest yields were obtained in sandy clay that also contained little mineral nitrogen. The optimum rate of nitrogen fertilizer did not correlate with the amount of mineral nitrogen in the soil. These results indicate that determining the amount of mineral nitrogen in soil before adjusting the rates of nitrogen fertilization, when growing cereals after cereals, may not be justified under Finnish conditions.

Index words: soil nitrogen, NH_4-N, NO_3-N, mineral nitrogen, Nmin method, mineralization, leaching, barley.

INTRODUCTION

Substantial quantities of mineral nitrogen may exist in the soil at sowing time. Amounts may reach up to more than 100 kg/ha in a one meter deep surface layer (BRUMMER and AURA 1974, SCHARPF and WEHRMANN 1975, LINDEN 1979). In several countries, the amount of mineral nitrogen in the soil is determined before adjusting the rates of nitrogen fertilization (e.g. WEHRMANN and SCHARPF 1979, KOLENBRANDER et al. 1981).

The variations in the level of mineral nitrogen in the soil, at the beginning of the growing period, depends for example, on the amount of unused fertilizer nitrogen left from the previous growing period. Also the crop grown, its fertilization and the soil type may have effects on the level of mineral nitrogen. The mineralization of organic nitrogen in soil during warm autumns and mild winters may be substantial. The low amounts of precipitation

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during the winter months has been found to be a decisive factor for the accumulation of mineral nitrogen within the root zone (LINDEN 1981, GARZ et al. 1982, GUSTAFSON and MATTSON 1982).

The knowledge of the mineral nitrogen reserves in soil is important because of the economy of nitrogen fertilization and the possible environmental effects from the leaching of excess nitrate.

In the present work, the quantities of mineral nitrogen in soils were studied under Finnish conditions, in order to evaluate their effects on the nitrogen fertilization requirements of barley.

MATERIAL AND METHODS

Five N-response experiments were established at three research stations in 1981. The experimental sites were selected to provide a variation of soil types common in southern Finland (Table 1). Four of the fields were mineral soils and one was peat (MTO2). The field of the LOU25 experiment was heavy clay with little finesand material while it was quite dominating in the plough layer of the LOU26 experiment. Silt was the main fraction in the field at the Sata-Häme Research Station.

The P and K fertilization of the experimental plots was based on results of soil testing. The weeds were controlled with MCPA. The levels of nitrogen were 0, 40, 80 and 120 kg/ha in four replications according to a randomized complete block design. The type of nitrogen fertilizer was calcium-ammonium-nitrate which was applied by using a combine drill. The 80 kg/ha treatment was close to the average rate of nitrogen fertilizer applied to barley in Finland. The barley (*Hordeum vulgare* L.) variety sown

Table 1. Soils of the experimental sites.

Site	Depth cm	pH	Org.C %	Tot.N %	Particle size composition % <2μm	2-20μm	20-60μm	>60μm
MTO1 Jokioinen	0-20	6,2	2,04	0,191	49	26	14	11
	20-40	6,5	0,57	0,096	58	24	12	6
	40-70	6,7	0,38	0,038	61	25	10	4
	70-100	7,0	0,32	0,034	63	27	9	1
MTO2 Jokioinen	0-20	5,1	16,8	0,780	-	-	-	-
	20-40	4,8	33,5	1,190	-	-	-	-
	40-70	4,8	31,7	1,480	-	-	-	-
	70-100	4,9	32,6	1,830	-	-	-	-
LOU25 Mietoinen	0-20	6,5	2,00	0,187	60	25	6	9
	20-40	6,4	1,60	0,134	63	25	5	7
	40-70	7,1	0,56	0,060	70	21	4	5
	70-100	7,0	0,45	0,045	70	27	2	1
LOU26 Mietoinen	0-20	5,4	1,53	0,149	31	19	20	30
	20-40	5,2	0,74	0,086	44	26	19	11
	40-70	5,4	0,57	0,068	54	29	12	5
	70-100	5,9	0,60	0,065	54	30	11	5
SAH461 Mouhijärvi	0-20	5,9	2,36	0,204	37	49	7	7
	20-40	6,2	0,54	0,075	32	55	8	5
	40-70	6,6	0,35	0,038	38	50	8	4
	70-100	6,6	0,38	0,027	45	43	5	7

was 'Pomo', but at SAH 461 the first year, oat was the experimental crop. The plots were 2,2 × 12 m. The experiment was repeated during three summers, at the same place.

Grain and straw yields were measured and samples were taken for determining the total amount of nitrogen. Straw was not plowed into the soil, for it was removed from the plots.

For determining the amount of soil mineral nitrogen (NH_4-N+NO_3-N), soil samples were collected annually in the spring before sowing, and in autumn after harvesting. Four layers in a depth of 1 m were sampled (Table 1). The sample representing the surface layer was composed of 20 subsamples. The samples of deeper layers were collected from four points on each plot. The samples were frozen to wait determinations.

Ammonium and nitrate were extracted, after thawing the frozen samples overnight in a refrigerator at +2 °C. A 40 ml volume of moist soil was taken and shaken with 100 ml of 2 M KCl for 16 hours. After filtration, ammonium N was measured from the extract with an autoanalyzer using an indophenol method (SELMER-OLSEN 1971). Nitrate was measured as nitrite with the sulfanilamid-naftylendiamin method after cadmium reduction (HENRIKSEN and SELMER-OLSEN 1970). Total nitrogen in the soil and plant samples was determined by using Kjeldahl's method.

RESULTS AND DISCUSSION

The amount of mineral nitrogen in the soil at the beginning of the growing period.

In the plots with 80 kg/ha N fertilizer, the amount of mineral nitrogen in heavy clay soil, before sowing, was lower than the amount of mineral nitrogen in other soils ranging from 22 to 27 kg/ha in the one meter surface layer during the four experimental years (Table 2). Also the two other soils having high clay content in the subsoil, MTO1 and LOU26, had lower amounts of mineral nitrogen than the silt dominated soil (SAH461). The highest amounts of mineral nitrogen in the soil before sowing time, was in peat. This amount ranged from 45 to 78 kg/ha.

In three of the five experimental sites, the amount of mineral nitrogen in the soil did not differ significantly from year to year, indicating that mineral nitrogen during spring did not vary much between years. Instead, there were significant differences between the experimental sites in the amount of mineral nitrogen.

Compared to the results obtained in the present study, higher amounts of mineral nitrogen, ranging from 46 to 56 kg/ha in a 0—60 cm layer, have been determined in Finnish soils where sugarbeet has been cultivated for several years (BRUMMER and AURA 1974). In Sweden after cereal, amounts of mineral nitrogen in a 90 cm layer ranging from 34 to 84 kg/ha have been reported by LINDEN (1983) and a wider range from 35 to 134 kg/ha by MATTSON (1983). In Central Europe, where warmer climate prevails especially during the winter period, higher mineral nitrogen contents in soils are more common than in Finland.

Table 2. Soil mineral N (kg/ha, 0—100 cm) at the beginning of the growing season. Fertilization 80 kg/ha N. Means that are not marked with the same letter, differ from each other at the 5 % level of significance (Tukey). Tested within rows (small letters) and within columns (capital letters).

	1981	1982	1983	1984
MTO1	40a BC	33a AB	30a A	33a A
MTO2	45a C	78b C	56a B	61ab C
LOU25	22a AB	22a A	27a A	25a A
LOU26	18a A	22ab A	37c A	32bc A
SAH461	53a C	45a B	42a AB	44a B

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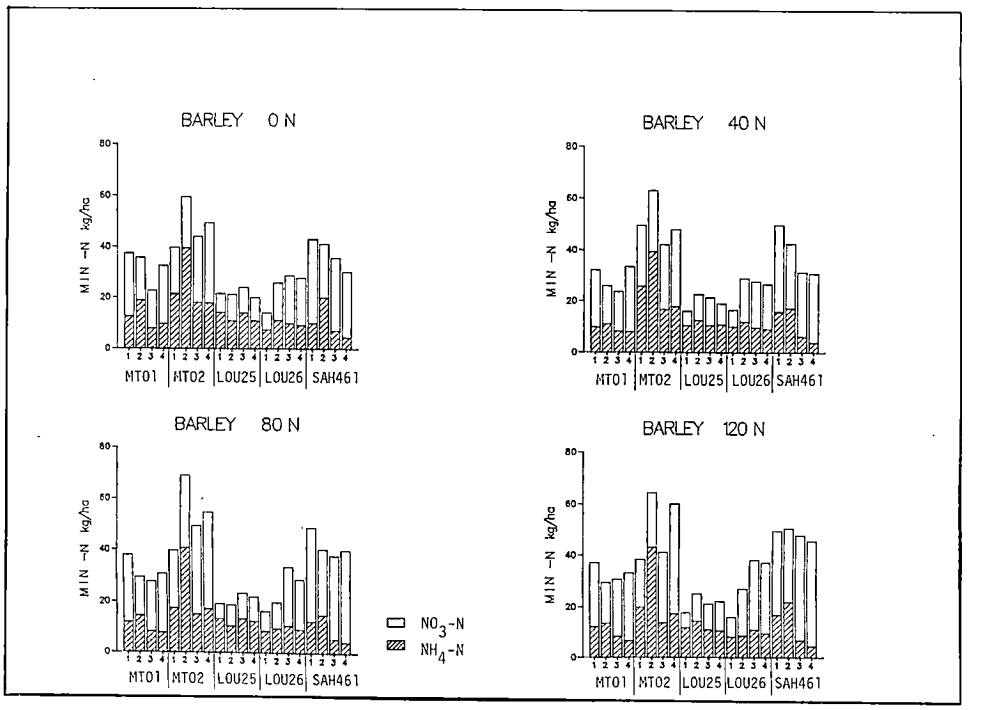

Fig. 1. Mineral nitrogen content of the top 100 cm layer of soil in spring before sowing at different sites and nitrogen fertilization levels in four years.

Amounts of mineral nitrogen in the one meter layer may range up to hundreds of kg/ha (STUMPE et al. 1978, WEHRMANN and SCHARPF 1979). In Finland, the low temperatures during autumn and spring, and freezing of soil in winter, do not favor the accumulation of mineral nitrogen, even in peats where total nitrogen reserves are great.

The effects of nitrogen fertilization on soils mineral nitrogen.

The amount of fertilizer did not have any significant effect on the amount of mineral nitrogen accumulated in the soil (Fig. 1). A slight trend towards higher amounts may be observed with higher rates, however.

More important than the level of fertilization for the mineral nitrogen in spring, appears to be the mineralization that occurs in autumn after harvesting and during early spring. The rate of mineralization averaged 11 kg/ha and the range was 0 to 30 kg/ha (Fig. 2). These quantities are higher than earlier assumed. Because microbial activity is possible down to ±0 °C temperatures, accumulation of such amounts is likely. This has been observed also elsewhere (LINDEN and NOUNO 1983).

It is not possible to estimate the amount of leaching nitrogen, but some net loss during winter was evident in the silt dominating soil when the highest amount of fertilizer was used (Fig. 3). The rates were 14 and 17 kg/ha during two of the three experimental years.

Based on the above observations, it may be concluded that the mineralization of nitrogen, during the winter season, in Finnish climate, remains at a relatively low level, compared to warmer areas where significant accumulations occur. Also, the leaching of nitrogen seems to remain negligible, if no higher than the optimum fertilizer rates are used.

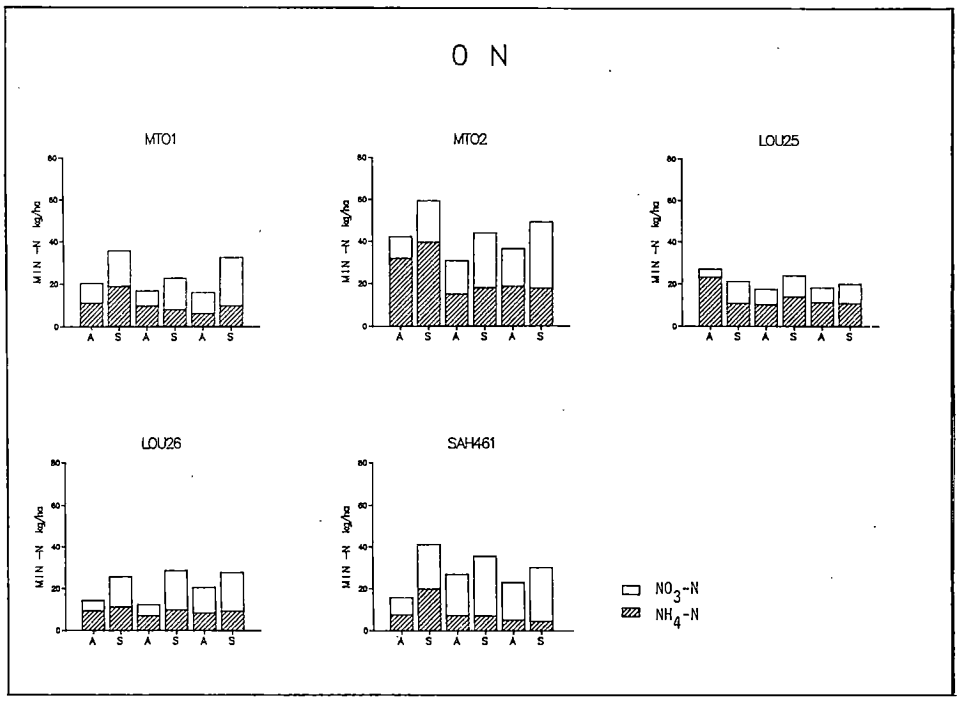

Fig. 2. The change in soil mineral nitrogen content in the top 100 cm layer from autumn (A) to spring (S). Check plots.

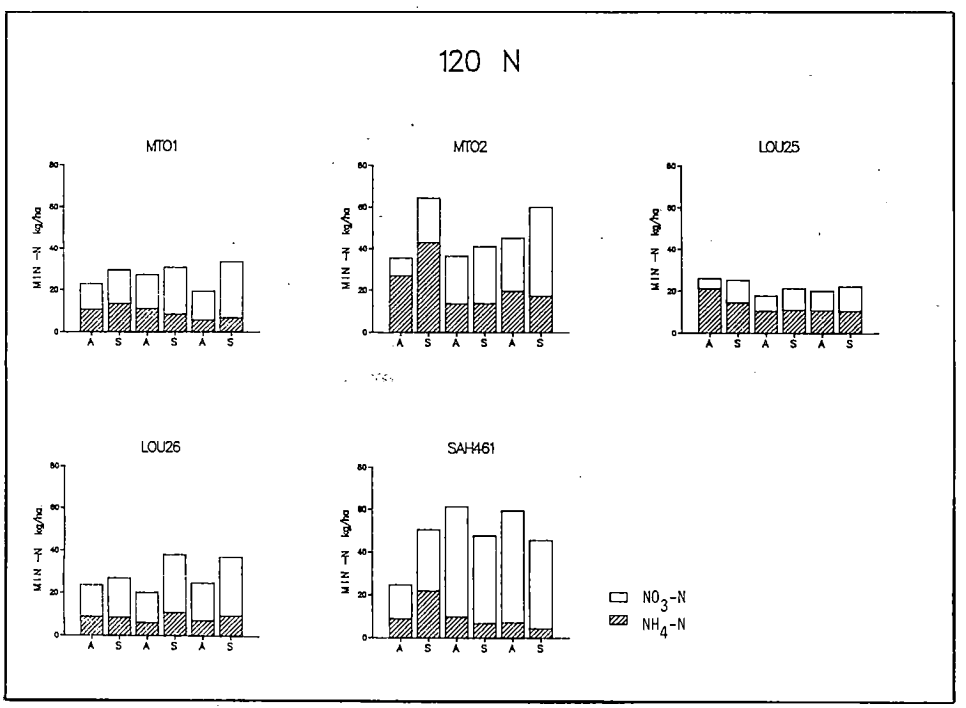

Fig. 3. The change in soil mineral nitrogen content in the top 100 cm layer from autumn (A) to spring (S). 120 N plots.

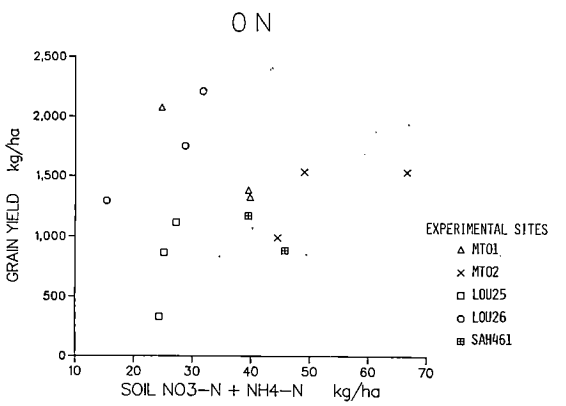

Fig. 4. Relationship between soil mineral nitrogen in spring before sowing and grain yield of barley on 0 N plots.

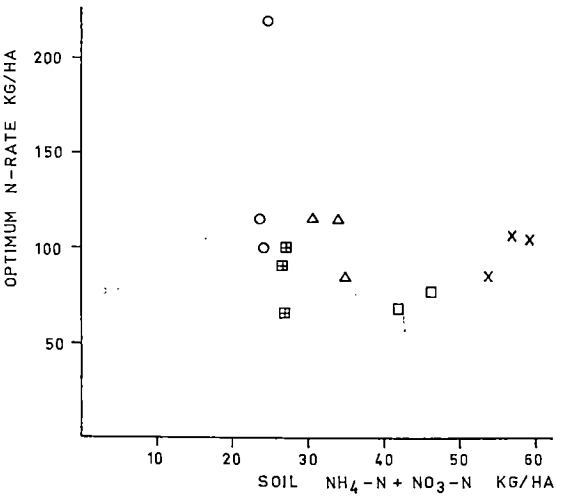

Fig. 5. Relationship between soil mineral nitrogen before sowing and the economically optimum rate for barley.

The effect of soil mineral nitrogen on barley yield.

Without nitrogen fertilizer the yields of barley ranged from 330 to 2210 kg/ha (Fig. 4). The lowest yield was obtained from heavy clay soil, where low amounts of mineral nitrogen were measured. The highest yields were obtained from the sandy clay soil, where the amounts of mineral nitrogen were also low. Therefore, the yield did not correlate with the amount of mineral nitrogen (NH_4-N+NO_3-N) nor with the ammonium or nitrate alone. The economically best fertilizer rate based on the present grain and nitrogen prices did not correlate with the amount of mineral nitrogen found in soil (Fig. 5).

The unclear effect of mineral nitrogen on the yield may be due to the narrow range of variation in mineral nitrogen content in spring. In studies where this dependence has been found, there has been wider variation in the amounts of mineral nitrogen found in soils (SCHARPF and WEHRMANN 1975, MATTSON 1983).

According to the results, determining the amount of mineral nitrogen in soil before adjusting the rates of nitrogen fertilization, when growing cereals after cereals, may not be justified under Finnish conditions. The differences in mineral nitrogen content after growing different crops, and the differences between soil types needs further investigation.

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SELOSTUS

Maan mineraalityppivarat ja ohran typpilannoitus

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Maatalouden tutkimuskeskus

Maan ammonium- ja nitraattityppivarojen määrää ja niiden vaihtelua tutkittiin ottamalla näytteitä metrin syvyyteen saakka keväisin ja syksyisin viidelle maalajille perustetuista kenttäkokeista. Tavoitteena oli selvittää, voitaisiinko määrittämällä keväisin maasta mineraalityppi täsmentää viljojen typpilannoitusta ja siten saada aikaan taloudellisia säästöjä sekä vähentää mahdollisia huuhtoutumisriskejä.

Koekentät sijaitsivat Maatalouden tutkimuskeskuksen mailla Jokioisissa sekä Lounais-Suomen ja Sata-Hämeen tutkimusasemilla. Niistä kolmen maalaji oli savi, joka vaihteli hietasavesta aitosaveen. Sata-Hämeessä hiesu oli vallitsevana lajitteena ja yksi koekentistä oli turvetta.

Maan mineraalitypen kokonaismäärä 0—1 metrin syvyydessä vaihteli keväällä 17—78 kg/ha, käytettäessä edellisenä kasvukautena 80 kg/ha typpeä. Typpilannoituksen lisääminen kohotti maan mineraalityppimääriä vain hiukan. Eri koevuosina samalla koepaikalla typpimäärien vaihtelu oli vähäistä, keskimäärin ±6 kg/ha. Erot olivat merkitseviä vain kahdessa viidestä koepaikasta. Sen sijaan koepaikkojen väliset erot olivat selvempiä. Vähiten mineraalityppeä oli savimaissa: aitosavessa 22—27 kg/ha, hietasavessa 18—37 kg/ha ja hiesusavessa 33—40 kg/ha. Maassa, jossa hiesu oli vallitseva lajite, typpimäärä vaihteli vuosittain 42—53 kg/ha. Eniten mineraalityppeä oli turvemaissa, 45—78 kg/ha.

Maan mineraalitypen määrä oli ohran typen oton seurauksena sadonkorjuun jälkeen yleensä pienempi kuin keväällä. Syksyn ja varhaiskevään aikana tapahtuneen orgaanisen typen mineraloitumisen vuoksi maan mineraalityppivarat usein lisääntyivät 0—30 kg/ha. Vain hiesumaassa mineraalityppimäärä pienentyi talvikauden aikana ilmeisesti huuhtoutumisen seurauksena suurinta typpimäärää, 120 kg/ha, käytettäessä ja maan mineraalityppimäärän ollessa 60—70 kg/ha. Siten talvikauden aikana oloissammekin typpeä mineraloituu jossakin määrin eikä huuhtoutuminen viljanviljelyssä näytä merkittävältä.

Ilman lannoitetyppeä ohran jyväsadot olivat 330—2210 kg/ha. Pienimmät sadot saatiin aitosavimaalla, jonka mineraalityppivarat olivat myös pienet. Toisaalta suurin keskisato saatiin hietasavella, jossa mineraalityppeä oli myös vähän. Taloudellisesti edullisin typpimääräkään ei riippunut maan mineraalitypestä. Näin ollen selvää riippuvuutta maan mineraalitypen ja sadon määrän välillä ei voitu todeta. Siksi maan mineraalitypen määrittäminen typpilannoituksen täsmentämiseksi jatkuvassa viljanviljelyssä ei näytä oloissamme perustellulta.

ANNALES AGRICULTURAE FENNIAE, VOL. 24: 125—129 (1985)
Seria AGROGEOLOGIA ET -CHIMICA N. 132 — Sarja MAA JA LANNOITUS n:o 132

SIMPLE EXTRACTION METHODS AS INDICATORS OF AVAILABLE SOIL NITROGEN SUPPLY

JOUKO SIPPOLA and RAIJA SUONURMI-RASI

SIPPOLA, J. & SUONURMI-RASI, R. 1985. **Simple extraction methods as indicators of available soil nitrogen supply.** Ann. Agric. Fenn. 24: 125—129. (Agric. Res. Centre, Dept. Soil Sci., SF-31600 Jokioinen, Finland.)

At room temperature, using the water extraction method, the amount of nitrogen extracted from mineral soils and peats, ranged from 1,8 to 7,7 mg/l soil. Boiling water, extracted almost ten times more nitrogen, ranging from 12 to 63 mg/l soil.

The absorption of light by the cold water extract, at 205 nm, accounted for 98 % of the variation in nitrogen uptake by ryegrass in a pot experiment. The variation accounted for by absorption at 260 nm of extracts made using cold, or boiling water were 96 %. The variation in nitrogen uptake accounted for by total N in these extracts was 83 and 94 %. NH_4-N extracted by 2 M KCl at + 80 °C accounted 94 %, and NO_3-N released during aerobic incubation, 85 % of the variation.

The methods based on, water extraction, and measurement of light absorption, appeared to be promising indicators in measuring the level of the available nitrogen supply in soil. Some of the advantages of these methods are simplicity, rapidity, and low costs.

Index words: soil N, availability, incubation, extractable N, water extraction, UV-absorption, ryegrass.

INTRODUCTION

The increasing cost of nitrogen fertilization makes it necessary to look after more appropriate use of this nutrient. One way to reach this goal is to determine the amount of nitrogen mineralized from soil reserves, before adjusting for nitrogen fertilization. This method could be of special importance in Finnish conditions where soils are rich in organic matter and hence contain large nitrogen reserves.

Due to the complexity, no method has been accepted for determining the potential of nitrogen mineralization in large scale (ØIEN and SELMER-OLSEN 1980, WHITEHEAD 1981). As an example of a simple method that of FOX and PIEKIELEK (1978) should be mentioned. In their procedure, organic matter is extracted with 0,01 M $NaHCO_3$ and determined by measuring the light absorption at 260 nm. The

results correlated well with the capacity of the soil to supply N.

The experiments in this study were conducted to evaluate some of the methods used for predicting the nitrogen supply in soils. The simple extraction methods were especially emphasized.

MATERIAL AND METHODS

Five cultivated peats with variable nitrogen contents, and three cultivated mineral soils with different texture and other properties were used as soil samples (Table 1). The soil samples were collected in autumn, then kept frozen, until the following spring. After thawing, the soils were passed through a 1 cm sieve and subsamples were taken for laboratory studies.

Pot experiment: A volume of 7,5 l of soil was put into a Brauchman-Kick pot. Four replicates were prepared. 1 g of ryegrass seed was sown as a test crop. Adequate P, K, Mg, S and trace elements were applied to guarantee a good growth. Pots were moistened to 60 % of their water holding capacity and kept at this level by watering two to three times a week. After the first cutting, severe nitrogen deficiency was evident, so nitrogen was added for the second yield at a rate of 750 mg/pot.

Table 1. Studied soils.

No	Location	Soil type	Total N %	Org. C %	C/N	pH $CaCl_2$	Corrected N uptake mg/pot
1	Laitila	Carex peat	1,89	30,1	16	4,9	1137
2	Hämeen-kyrö	Carex peat	2,52	31,9	13	4,1	1426
3	Kuru	Carex peat	1,18	30,9	26	4,5	1034
4	Jokioinen	Carex peat	1,87	28,3	15	4,8	1274
5	Urjala	Carex peat	2,15	32,3	15	4,6	1330
6	Jokioinen	Fine-sand	0,15	1,8	12	6,0	590
7	Jokioinen	Heavy clay	0,45	5,8	13	4,7	679
8	Nakkila	Silt	0,28	2,6	9	5,6	735

Similarly, nitrogen fertilizer was added the second summer when the pot experiment was continued. 70 % of the added fertilizer nitrogen was subtracted of the total nitrogen uptake by seven harvests made. The difference was assumed to be the mineralization of nitrogen reserves in the soil.

The total amount of N, in soil and ryegrass: Soil (1 g) and ryegrass (0,5 g) were digested with a H_2SO_4-K_2SO_4-$CuSO_4$-mixture, and NH_4-N in the digest was estimated by automated colorimetry, using sodium phenate and sodium hypochlorite.

Determining the amount of mineral nitrogen (NO_3-N and NH_4-N) in soil: Soil (40 g) was shaken with 2 M KCl (100 ml) overnight and then the suspension was filtered. NO_3-N was determined in the filtrate by automated colorimetry, involving a reduction to NO_2 with a column of cadmium filings. The NO_2 was estimated with the sulfanilamide-naphtylethylamine method. NH_4-N was determined the same way as soil total N.

Methods to estimate available soil nitrogen supply:

Aerobic incubation : 0,5 l of moist soil was incubated for three months, at 70 % water holding capacity. The temperature was varied daily: 6 h at +11—13 °C, 18 h at +17—19 °C. The released nitrate was measured.

Hot KCl extraction (ØIEN and SELMER-OLSEN 1980): A 4 g soil sample was mixed with 40 ml of 2 M KCl, kept at 80 °C in closed bottle for 20 h. The NH_4-N was determined.

$NaHCO_3$ extraction (FOX and PIEKIELEK 1978): A volume of 10 ml soil was shaken in 100 ml of 0,01 M $NaHCO_3$-solution for 15 minutes, and then centrifuged. The light absorption at 260 nm, and total N in the extract were measured.

Cold water extraction: A volume of 25 ml soil was shaken in 100 ml water for one hour and then centrifuged. The light absorption of samples diluted with water (1:10), at 205 and 260 nm and the total N in the extract were measured.

Hot water extraction (KEENEY and BREMNER 1966): A volume of 10 ml soil was boiled in 100 ml of water under a reflux condenser for one hour. The light absorption at 260 nm, and the total N in centrifuged extract were measured.

RESULTS AND DISCUSSION

In Finnish climate the mineralization of organic nitrogen in peats is so slow that nitrogen fertilization is needed when these soils are used in practical agriculture. Therefore the nitrogen fertilization of the experimental pots, when testing for nitrogen mineralization, simulated the situation in normal farming. A reasonable growth was obtained with additional nitrogen. This addition, however, was likely to impair the accuracy of estimating the nitrogen mineralized of reserves in the soil (Table 1). The 70 % uptake rate of nitrogen fertilizer, which was used when calculating the amount of nitrogen mineralization, was based on earlier experiments. The wide range of soil types used, led, however, to a rather high degree of explanation

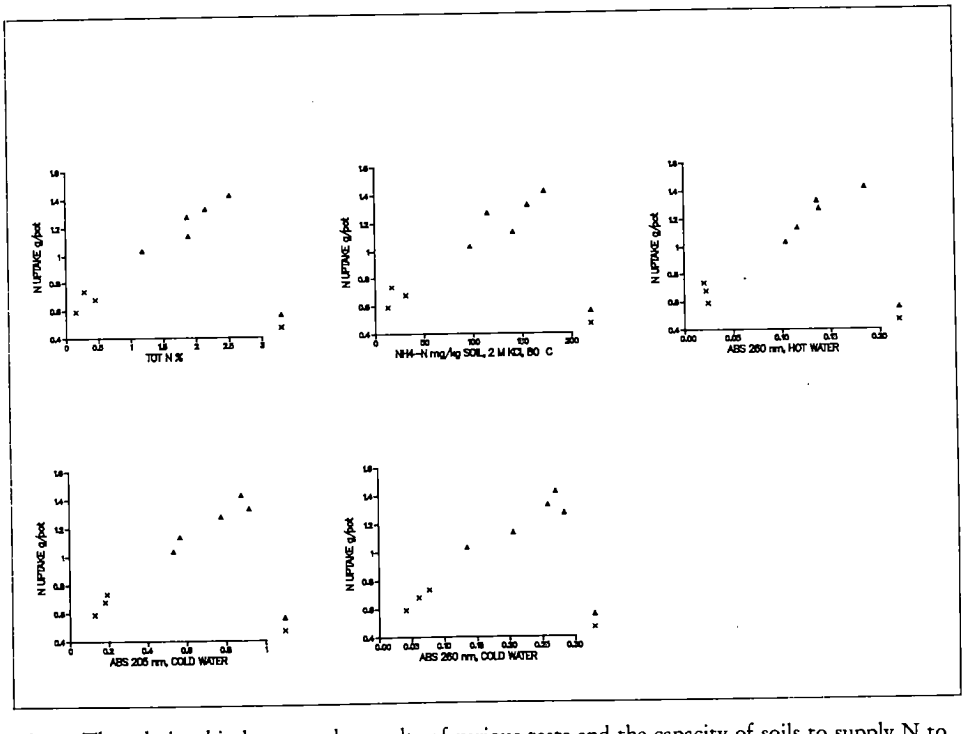

Fig. 1. The relationship between the results of various tests and the capacity of soils to supply N to ryegrass, X=mineral soils, Δ=peat soils.

Table 2. Percentage of variation in ryegrass N yield accounted for by the various methods for predicting soil N supply.

Total soil N	96
2 M KCl, 80 °C, NH_4-N	94
$NaHCO_3$, tot N	92
$NaHCO_3$, abs 260 nm	96
Water, 20 °C, tot N	83
Water, 20 °C, abs 205 nm	98
Water, 20 °C, abs 260 nm	96
Water, boiling, tot N	94
Water, boiling, abs 260 nm	96
Incubation, aerobic, NO_3-N	85

by each method. Overall the differences between methods were relatively small (Table 2, Fig. 1).

Many studies, including this one, have shown that the total amount of nitrogen in the soil is a good indicator of the available N supply. All the methods that involved determination of total nitrogen in extracts, including the 2 M KCl heat extraction method developed by ØIEN and SELMER-OLSEN (1980) accounted for a lower percentage of variation in nitrogen uptake than soil total N. This deviates from the reports, where the extractants have been found to be promising indicators of the available nitrogen supply in soils (FOX and PIEKIELEK 1978, MICHRINA et al. 1981). The low portion of variation accounted for by the incubation method is surprising, because incupation methods have been commonly used to indicate the available N supply in soils.

According to the results the light absorption of extracts correlated better than their total nitrogen content with nitrogen uptake of ryegrass in all cases tested. Especially the absorption at 205 nm correlated well with the nitrogen uptake in ryegrass. The absorption at 205 nm was likely caused by NO_3-N, and a method to determine the nitrate content based on absorption at this wavelength has been developed (CAWSE 1967). Organic matter is the major interference in determining nitrate. When the absorption of a water extract is measured the nitrate and organic matter are estimated. This may be the reason for the good correlation with plant uptake.

The water extraction method at room temperature was weakest of the extraction methods. The amounts of soluble nitrogen ranged from 1,8 to 7,7 mg/l soil. The hot water method extracted almost ten times more nitrogen, ranging from 12 to 63 mg/l soil. The cold water extractable amounts were less than one thousandth of the total nitrogen in the soil. Evidently, the water extraction methods selectively extract soil organic matter. The easily extractable forms are likely to be susceptible to fast mineralization. The water extractable organic matter consists mainly of microbially derived substances (VERSTRAETEN et al. 1964, STANFORD 1968).

The cold water extraction method could easily be adopted for routine use. It would be a cheap method when no reagents would be needed. However, because in the pot experiment methods were not clearly separated on the basis of their ability to indicate the nitrogen uptake by ryegrass, further testing of the water extraction method is needed.

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SELOSTUS

Yksinkertaiset uuttomenetelmät maan typenluovutuskyvyn osoittajina

JOUKO SIPPOLA ja RAIJA SUONURMI-RASI

Maatalouden tutkimuskeskus

Typen hinnan kohoaminen on lisännyt tarvetta entistä harkitumpaan typpilannoitteiden käyttöön. Kasvukauden aikana tapahtuvan maan orgaanisen aineen typen mineraloitumisen huomioon ottaminen on yksi tapa täsmentää typpilannoitusta. Vapautuvan orgaanisen typen huomioon otto on erityisen tärkeää, sillä maittemme typpivarat ovat huomattavan suuret. Näin on laita erityisesti turvemaissa.

Maasta mineraloituvan typen määrittämiseen ei ole kehitetty rutiinikäyttöön soveltuvaa menetelmää. Esitetyt testit ovat yleensä työläitä ja vievät paljon aikaa. Tämän tutkimuksen tavoitteeksi otettiin sellaisten menetelmien testaus ja kehittäminen, jotka soveltuvat käytäntöön entistä paremmin.

Vertailtavina menetelminä olivat seuraavat: muhitus, uutto 2 M KCl:lla 80 asteen lämpötilassa, uutto 0,01 M $NaHCO_3$:lla, uutto kiehuvalla vedellä sekä uutto huoneen lämpöisellä vedellä. Riippuen menetelmästä uutteesta mitattiin joko totaali-, NH_4- tai NO_3-N. Eräistä uutteista mitattiin niiden kyky absorboida valoa uuttuneen orgaanisen aineen määrittämiseksi. Saatuja tuloksia verrattiin rairuohon astiakokeessa ottamaan typpeen. Koemaina oli viisi turvetta ja kolme kivennäismaata.

Tulosten mukaan uutto huoneenlämpöisellä vedellä ja uutteen absorbanssin mittaus 205 tai 260 nm aallonpituudella selitti parhaiten rairuohon typen ottoa. Vesi ilmeisesti uuttaa maasta helposti mineraloituvan orgaanisen typen fraktion. Uuttuneet kokonaistyppimäärät vaihtelivat 1,8:sta 7,7:ään mg/l maata, mikä oli vähemmän kuin tuhannesosa maan kokonaistyppimäärästä. Vesiuutto ja uutteen absorbanssin mittaus mineraloituvan typen arvioimiseksi on yksinkertainen ja halpa menetelmä, joka sopii hyvin rutiinityöskentelyyn. Astiakokeessa saadut tulokset tulisi kuitenkin varmistaa kenttäkokein menetelmän käyttökelpoisuuden varmistamiseksi.

ANNALES AGRICULTURAE FENNIAE, VOL. 24: 131—137 (1985)
Seria AGROGEOLOGIA ET -CHIMICA N. 133 — Sarja MAA JA LANNOITUS n:o 133

THE EVALUATION OF THE MAGNESIUM STATUS OF FINNISH SOIL TYPES

RAILI JOKINEN

JOKINEN, R. 1985. **The evaluation of the magnesium status of Finnish soil types.** Ann. Agric. Fenn. 24: 131—137. (Agric. Res. Centre, Dept. Soil Sci., SF-31600 Jokioinen, Finland.)

Acid ammonium acetate extractable magnesium was determined from topsoil material (c. 30 000 samples) that was collected by agricultural advisors and farmers.

In the whole material and in the individual soil types except for heavy clay, the frequency distribution in magnesium content classes was skewed to the left. The too high estimates about the magnesium status of Finnish soil types seemed to be made according to the mean of the extractable magnesium content.

A great majority (about 75 %) of the coarsest mineral soils (glacial till, sand, fine sand) were deficient in magnesium, and contained extractable magnesium less than 125 mg/l soil. Also in finer finesand, mull and peat soils the number of samples with low magnesium content was considerable. According to the magnesium content of clay soils, the need for fertilization would be very unlikely except for gyttja clay.

Index words: glacial till, sand, fine sand, silt, sandy clay, silty clay, heavy glay, gyttja clay, mull, peat, extractable magnesium.

INTRODUCTION

In the 1960's, signs of magnesium deficiency were detected in cereal shoots. Magnesium fertilization and liming with dolomitic limestone were at that time uncommon, and as late as in 1972, the proportion of calcitic limestone compared to the total amount of liming agents sold for agricultural purposes was still about 80 % (JOKINEN 1981).

According to KURKI (1972), and SIPPOLA and TARES (1978), the magnesium content (acid ammonium acetate extractable) in all soil types averaged 180 mg/l soil. They also reported the mean contents of individual soil types, and their results showed that in coarse mineral soils the magnesium content remained below the safe content which was proposed by JOKINEN (1981) to be about 150 mg/kg soil. And when compared international, the Finnish soils are also relatively poor in magnesium (SILLANPÄÄ 1982).

The aim of this study was to evaluate the magnesium status in Finnish agricultural soil types according to frequency distribution, mean±standard deviation, mode and median of acid ammonium acetate extractable magnesium content.

MATERIAL AND METHODS

The soil sample material was taken in 1966—70 by agricultural advisors and farmers. The analyses were made by the Soil Testing Service, and the results of about 380 000 soil samples were published by KURKI (1972). Thereafter, the analysed data was donated to the Department of Soil Science, Agricultural Research Centre. From that material the magnesium analyses concerning soils cultivated with cereals and leys were selected. This material consisted of the analyses of about 30 000 samples representing agricultural topsoils.

The soils were air-dried and crushed to pass a 2 mm sieve, then analysed for acid ammonium acetate (VUORINEN and MÄKITIE 1955) extractable magnesium by atomic absorption spectrophotometry. The magnesium contents were measured on the volume basis of the air-dried soil (mg/l). The soil type was determined by sense perceptions and particle size analysis (ELONEN 1971).

The material was classified in eleven groups according to soil type as follows:

Mineral soils

Coarse mineral soils

1) glacial till, 2) sand, 3) fine sand, 4) finer finesand, 5) silt

Fine mineral (clay) soils

6) sandy clay, 7) silty clay, 8) heavy clay, 9) gyttja clay

Organogenic soils

10) mull, 11) peat.

Further, each soil type was classified according to magnesium content: ≦ 25, 26—75, 76—125, 176—225 ... (class interval 50 mg/l). The frequency distribution %, the mean±standard deviation, the median and the mode of the magnesium content were calculated in all soil types. The class with the highest frequency was regarded as the mode of magnesium content (STEEL and TORRIE 1960).

RESULTS AND DISCUSSION

The detection of magnesium deficiency symptoms in plants may have led the farmers to soil magnesium testings. Therefore, it was possible that the soil samples of this material might have represented the lower part of the magnesium content range. Yet, the found high contents pointed out to slight choice.

The mean of acid ammonium acetate extractable magnesium content in this material (181±156 mg/l), in the respective material collected ten years later (189 mg/l) reported by KURKI (1982), and in the 2000 samples from timothy leys (178±150 mg/l) reported by SIPPOLA and TARES (1978) are all identical. These results indicate that Finnish agricultural soils, on the average, are poor with magnesium in comparison to the international mean (489±437 mg/l) of about 2000 samples studied by SILLANPÄÄ (1982).

Because the analyses were based on the volume of soil, the comparisons of magnesium content in mineral soils and organogenic soils were possible. However, the drying and grinding of the soils alter the volume weight of organogenic soils more than the volume weight of mineral soils (ERVIÖ 1970). The wide range of magnesium content in mull soils (15—4250 mg/l) and in peat soils (10—2200 mg/l) was partly caused by the sample preparation procedures, and also by the samples taken from the areas fertilized or limed with magnesium. In mineral soils, the highest magnesium content

varied between 725 mg/l (sand) and 1400 mg/l (heavy clay). In clay soils, the magnesium contents of 1000 mg/l are not rare in Finnish soils.

In the whole material, the distribution of samples in magnesium content classes was skewed to the left, and the highest frequency was observed in the class 76—125 mg/l (Fig. 1 a). The mean of the magnesium content (181±156 mg/l) was considerably higher than the median (131 mg/l).

In glacial till, sand anf fine sand soils the difference between the mean (101±69, 99±80 and 107±80 mg/l, respectively) and the median (91, 77 and 81 mg/l, respectively) increased in that given order. About 40 % of the samples contained 26—75 mg/l magnesium, and about 75 % contained 26—125 mg/l magnesium (Fig. 1 b, c, d).

The mean magnesium content of finer finesand (145±90 mg/l) was lower than that of silt (195±99 mg/l). In both soils the median was 24 mg/l lower than the mean. The mode of magnesium content in silt (126—175 mg/l) was in the next higher class than the mode in finer finesand (76—125 mg/l). The three most frequent classes of finer finesand (26—175 mg/l) included about 70 % of the samples, and of silt (76—225 mg/l) about 65 % of the samples (Fig. 1 e, f).

In heavy clay, the distribution in magnesium content classes was near the normal distribution, but in other clays the distribution was skewed to the left (Fig. 1 g, h, i, j). The concentration of samples in few magnesium content classes was not in clay soils so obvious than in coarse mineral soils. The soil types gyttja clay, sandy clay, silty clay, and heavy clay are listed in order of the decreasing difference between the mean (287±200, 383±183, 406±164, 669±234 mg/l) and the median (248, 350, 376, 648 mg/l).

The mull and peat soils seemed to have deviated from each other according to the mean content (194±161, 179±122 mg/l) more than according to the median (161, 152 mg/l). The almost identical frequency distribution diagrams indicated the highest occurrence of samples containing magnesium 76—125 mg/l (Fig. 1 k, l).

In an earlier study the minimum requirement of ammonium acetate extractable magnesium content for sufficient magnesium supply was estimated to about 150 mg/kg soil (JOKINEN 1981). Still, the material of the present study was classified to correspond to the limit of 125 mg/l. Below that magnesium content the requirement for fertilization would be essential for several agricultural plants.

According to the extractable magnesium content values, glacial till, sand, and fine sand soils were chiefly poor with this nutrient. Thus the need of magnesium fertilization was obvious for about 75 % of the samples. In finer finesand, mull, and peat soils as well as in silt soils, the proportion of samples with low magnesium content was considerable. For these soil types the results of soil testing are the only reliable estimate for the magnesium fertilization.

The group of clay soils seemed to be more heterogenic than coarse mineral soils and organogenic soils. In all of the four clay soil types also low contents of magnesium were analysed. Most clay soils had a good magnesium content without any need of a magnesium fertilization, the gyttja clay made an exception.

When the distribution is skewed, the mean is quite misleading measure and the meadian and the mode more informative measures of the central tendency (STEEL and TORRIE 1960). The high percentage of the standard deviation on the mean is an indication of skewed material, but not on the direction of the skewness.

If the comparisons between the soil types were based only on the mean±standard deviation, the estimations of the magnesium status in finer finesand, silt, clay (excluding heavy clay), and organogenic soils would have been

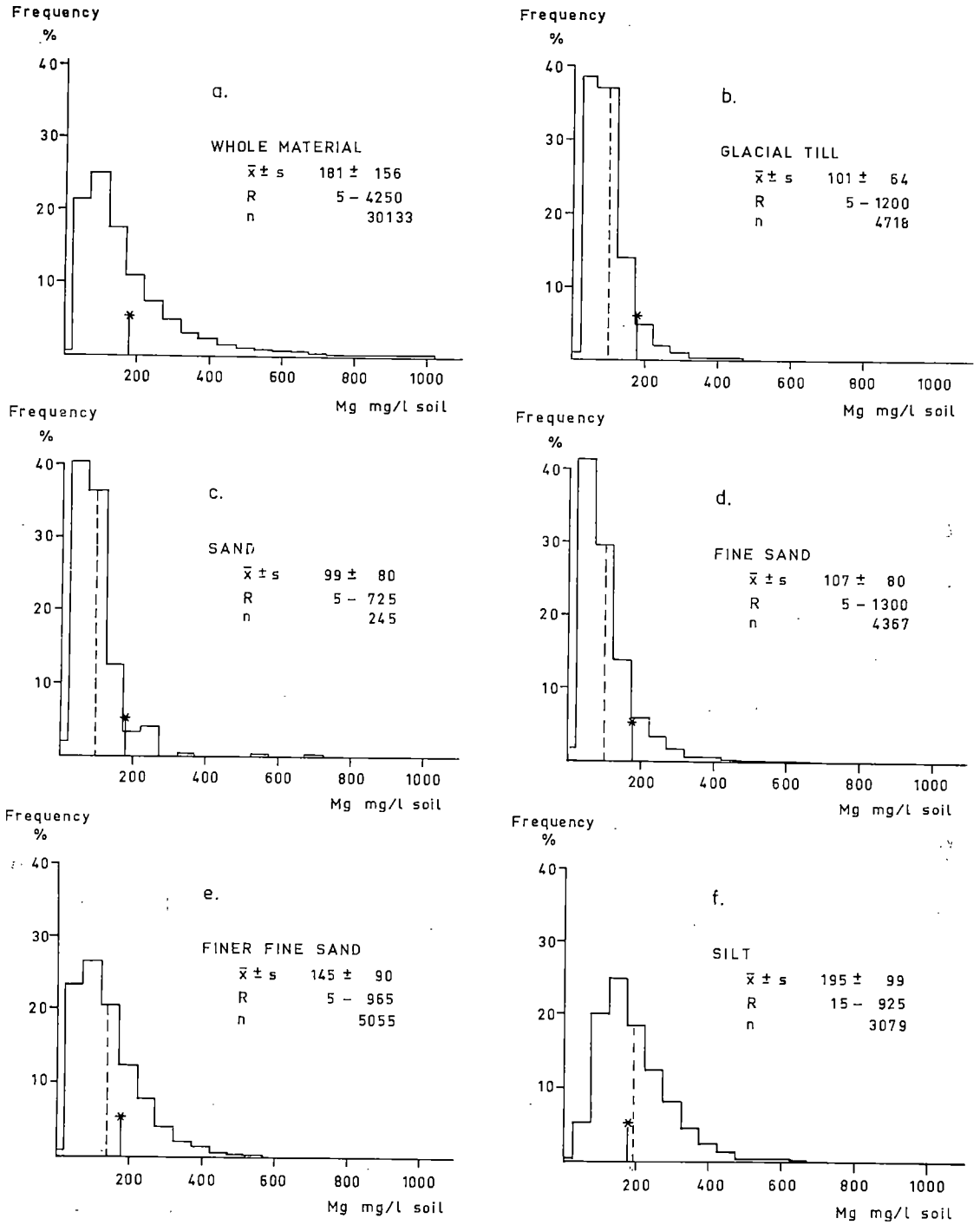
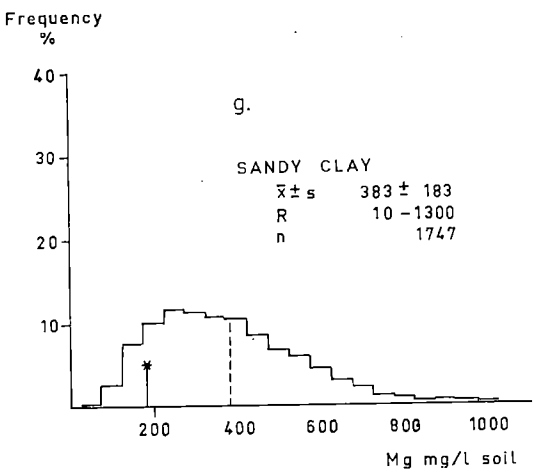
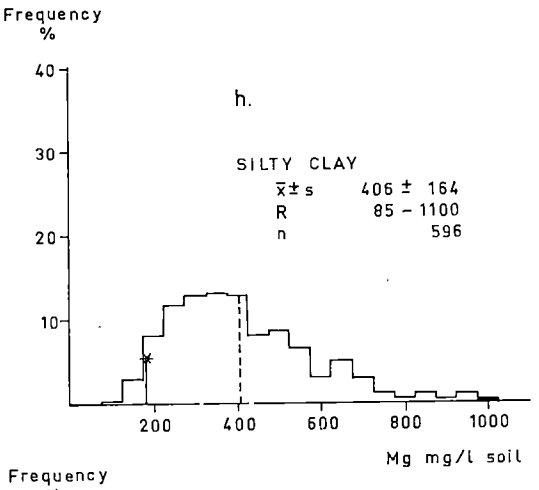
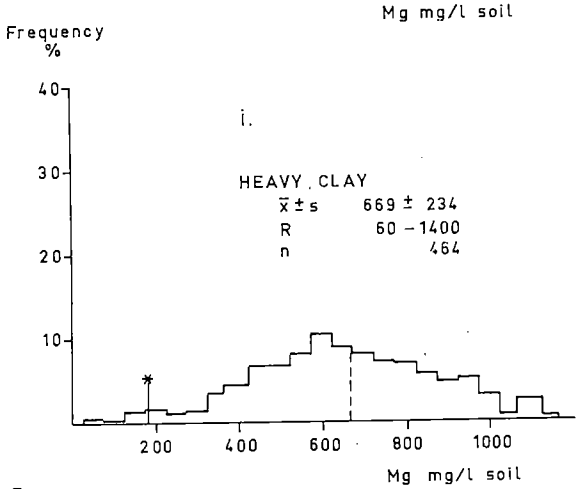
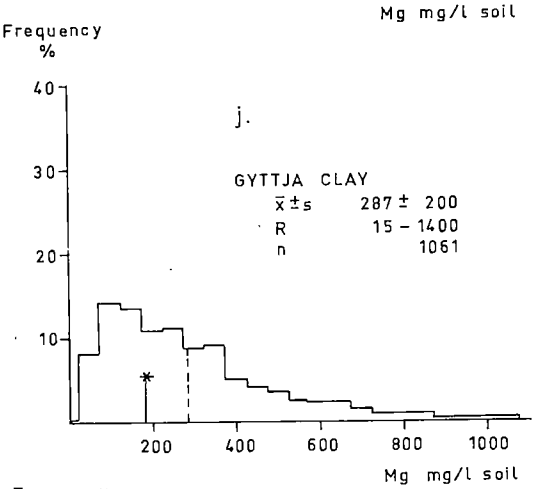


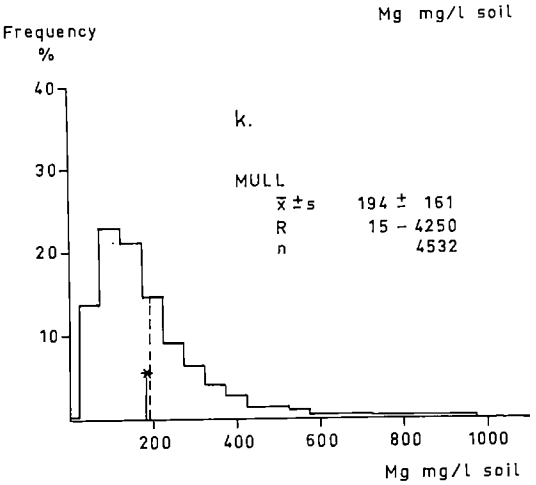
Fig. 1. The frequency distribution of acid ammonium acetate extractable magnesium in the whole soil sample material (a) and in different soil types (b—l). Unbroken line with star (————*) = mean of the whole material, broken line (- - - -) = mean of the soil type in question. ($\bar{x}$ = mean, s = standard deviation, R = range, n = number of samples).

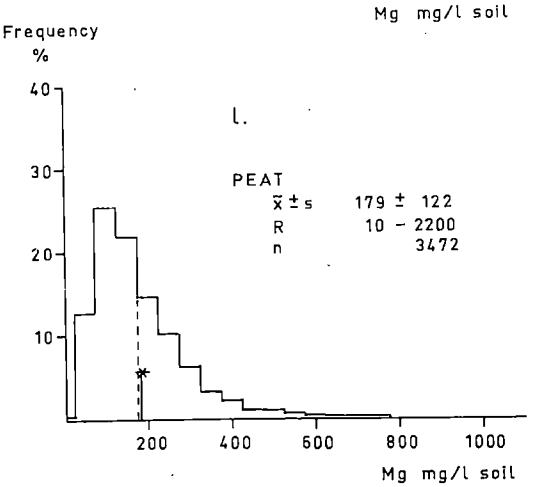

Frequency
%
40
30
20
10
g.
SANDY CLAY
x̄ ± s 383 ± 183
R 10 - 1300
n 1747
200
400
600
800
1000
Mg mg/l soil


Frequency
%
40
30
20
10
h.
SILTY CLAY
x̄ ± s 406 ± 164
R 85 - 1100
n 596
200
400
600
800
1000
Mg mg/l soil


Frequency
%
40
30
20
10
i.
HEAVY CLAY
x̄ ± s 669 ± 234
R 60 - 1400
n 464
200
400
600
800
1000
Mg mg/l soil


Frequency
%
40
30
20
10
j.
GYTTJA CLAY
x̄ ± s 287 ± 200
R 15 - 1400
n 1061
200
400
600
800
1000
Mg mg/l soil


Frequency
%
40
30
20
10
k.
MULL
x̄ ± s 194 ± 161
R 15 - 4250
n 4532
200
400
600
800
1000
Mg mg/l soil


Frequency
%
40
30
20
10
l.
PEAT
x̄ ± s 179 ± 122
R 10 - 2200
n 3472
200
400
600
800
1000
Mg mg/l soil

too high. The mean of these soils was in the right half of the distribution diagram. Some samples with high magnesium content transfer the mean even further to the right. In this kind of cases, the frequency distribution is the best indicator of the magnesium status. In the coarsest mineral soils the frequency distribution, the mode, the median and the mean were almost equally powerful indicators of the magnesium status.

Frequency distributions concerning individual soil types were not presented earlier. The frequencies in fairly large soil sample materials, given e.g. at five or ten year intervals, would be important for the studies concerning general trends of the magnesium status in soil types. The same kind of diagrams on the contents of other nutrients (e.g. Cu) may also have practical value.

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SELOSTUS

Suomalaisten maalajien magnesiumpitoisuus

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Maatalouden tutkimuskeskus

Viljavuuspalvelu Oy luovutti noin 30 000 maanäytteen analyysitulokset tämän tutkimuksen aineistoksi.

Hienojen hietojen ja sitä hienompien kivennäismaiden samoin kuin eloperäisten maiden magnesiumtilaa näytti kuvaavan parhaiten jakautuma eri magnesiumpitoisuuden luokkiin. Sen perusteella voidaan myös verrata eri maalajeja keskenään luotettavasti. Pitoisuuden keskiarvo osoittautui huonoimmaksi magnesiumtilan ilmaisijaksi. Moreeneilla, hiekoilla ja karkeilla hiedoilla jakautuma ja pitoisuuden keskiarvo olivat lähes saman arvoiset kuvaajat.

Aikaisemmin ei ole esitetty maalajittaisia yksittäisen ravinteen pitoisuuden luokitteluun perustuvia tilastoja. Ne olisivat ilmeisesti käyttökelpoisia tutkittaessa eri ravinteiden pitoisuuksien muutoksia pitkällä aikavälillä. Jakautuman perusteella voitaisiin lisäksi arvioida ravinteiden oikeita käyttökohteita. Esim. kuparia koskevat tiedot olisivat avuksi etsittäessä tämän kalliin ravinteen puutosalueita.

Maan magnesiumpitoisuuden turvallisena alarajana pidetään arvoa 150 mg/l. Tässä tutkimuksessa käytettiin kuitenkin poikkeuksellisesti arvoa 125 mg/l.

Moreenit, hiekat ja karkeat hiedat sisälsivät yleensä niukasti magnesiumia ja lannoituksen tarve näytti olevan ilmeinen noin 75 %:lle näytteistä.

Hienojen hietojen, hiesujen sekä multa- ja turvemaiden ryhmissä oli vähän magnesiumia sisältävien näytteiden osuus huomattava. Riittävän pitoisuuden omaavia näytteitä oli kuitenkin yli puolet kunkin maalajin aineistosta. Magnesiumlannoituksen tarve voidaan näillä maalajeilla todeta luotettavasti vain maa-analyysin perusteella.

Savimaissa, erityisesti liejusavissa, todettiin alhaisiakin magnesiumpitoisuuksia mikä osoittaa, että eräissä tapauksissa (noin 20 % liejusavista, 1—3 % muista savista) magnesiumlannoitus saattaa olla tarpeen myös savimaille. Suurin osa savimaiden näytteistä sisälsi riittävästi magnesiumia, vaikka pitoisuus olikin alle maalajin keskiarvon yli 50 %:ssa näytteistä.

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Seria AGROGEOLOGIA ET -CHIMICA N. 134 — Sarja MAA JA LANNOITUS n:o 134

MACRONUTRIENT CONTENTS OF DIFFERENT PLANT SPECIES GROWN SIDE BY SIDE

HÅKAN JANSSON, TOIVO YLÄRANTA and MIKKO SILLANPÄÄ

JANSSON, H., YLÄRANTA, T. and SILLANPÄÄ, M. 1985. **Macronutrient contents of different plant species grown side by side.** Ann. Agric. Fenn. 24: 139—148. (Agric. Res. Centre, Inst. Soil Sci., SF-31600 Jokioinen, Finland.)

The contents of five macronutrients N, P, K, Ca and Mg in the dry matter of various parts of 17 crops were compared. The crops were grown side by side at nine experimental sites in various parts of Finland corresponding well to typical Finnish soils and growing conditions.

The highest average N, P, K and Mg contents of various plants exceeded the lowest average contents by factors varying from five to eight. In the case of Ca the difference was 60-fold.

Cereal grains were generally high in P, medium in N and Mg, but low in K and Ca. Their straws contained little N, P and Mg but had medium K and Ca contents. Onion bulb and potato tuber were generally low in all five macronutrients while those of grasses were of a medium high level, rye grass being somewhat richer in all macronutrients than timothy.

The N, Ca and Mg contents of leguminous crops were usually among the highest with the exception of the low Ca and Mg contents of pea seed. The P and K in legumes were of a medium level, with the high P and low K contents of pea seed, however, being an exception.

Root crops had generally high macronutrient contents in their tops but their roots were often low. Great differences between various plant parts were also measured in turnip rape, the seeds of which were very rich in N and P but the stalks very low in these. High Ca and Mg and low K contents were also typical of turnip rape.

Index words: macronutrient content, nitrogen, phosphorus, potassium, calcium, magnesium, cereals, timothy, red clover, rape, rye grass, pea, onion, turnip, carrot, potato, beet, swede.

INTRODUCTION

Macronutrient fertilization of different plant species is usually based on soil analysis while in case of micronutrients, plant analysis often plays a more important role. However, the macronutrient requirements of various plant species and even varieties vary considerably as shown by numerous fertilizer trials and vast experience in practical farming. It has been

assumed that under normal growing conditions the uptake of macronutrients by plants well reflects their requirements for different nutrients. Furthermore knowledge of the macronutrient contents of different plant species is of importance in estimating the quality of food and feedstuff, especially from the mineral nutrition point of view.

Data on the macronutrient contents of different plant species usually originates from dissimilar growing conditions and soils, consist of divergent cultivars and, consequently, are not directly comparable. Differences in the physiological age of plants at sampling and varying practice concerning which parts of the plants are analysed further decrease comparability of analytical results. In order to meet the conditions of comparability a number of crops were grown side by side at nine sites in different areas of Finland representing typical Finnish growing conditions. All samples were analysed in one laboratory by the same methodology.

MATERIAL AND METHODS

The experimental soils at nine research stations consisted of three clay soils (Sites 2, 3 and 5), three organogenic (7, 8, 9), two finesand (4, 6) and a sandy loam (1) soil the properties of which are shown in Table 1.

Soil phosphorus, potassium, calcium and magnesium were analysed after an acid ammonium acetate (pH 4,65) extraction (VUORINEN and MÄKITIE 1955), P was analysed colorimetrically, K and Ca by flame photometry and Mg by atomic absorption spectrophotometry. Total soil N was determined by the Kjeldahl method using Tecator equipment. Particle size distribution was determined by the pipette method (ELONEN 1971), organic C with a Leco CR-12 carbon determinator (SIPPOLA 1982) and pH($CaCl_2$) from a 0,01 M $CaCl_2$ suspension (v/v 1 : 2,5).

The layout of the trials, crops, cultivars, sampling methods and times are described in detail in an earlier paper concerning micronutrients (YLÄRANTA and SILLANPÄÄ 1984). To guarantee satisfactory growth each crop was fertilized with compound fertilizer containing 53 kg N, 23 kg P, 44 kg K, 33 kg Ca and 2,5 kg Mg per hectare. The fertilizer was placed in the rooting zone, except in case of grass crops which were fertilized by the broadcast method.

Table 1. General soil properties and extractable macronutrients of topsoils at the experimental sites.

	Particle size distr. (%)				Org. C	pH ($CaCl_2$)	Electr. cond. 10^{-4}S	N (total)	P	K (extractable)	Ca (extractable)	Mg
Site	<,002	,002 -,02	,02 -,2 mm	>,2 mm	%		cm	%	mg/l	mg/l	mg/l	mg/l
1. Häme Res. Station	15	24	26	35	1,7	5,3	0,9	0,13	10,0	150	1400	70
2. Sata-Häme Res. Sta.	36	48	11	5	3,8	5,1	2,0	0,27	11,2	310	1600	200
3. S.W. Finland Res. Sta.	34	19	46	1	1,7	4,0	1,6	0,15	4,8	210	500	170
4. S. Savo Res. Sta.	4	8	74	14	4,4	4,8	1,5	0,19	9,6	180	1000	65
5. Inst. of Soil Science	70	21	8	1	4,7	4,5	1,8	0,32	9,6	700	1750	235
6. Central Finland Res. Sta.	4	9	84	3	1,5	4,8	0,9	0,11	10,3	100	700	25
7. Kainuu Res. Sta.	-	-	-	-	47	4,1	1,3	2,71	11,1	40	850	180
8. N. Savo Res. Sta.	26	42	26	6	16	4,6	4,2	0,94	4,3	60	1700	150
9. S. Ostrobothnia Res. Sta.	28	44	28	-	19	4,9	2,3	1,26	4,7	90	3000	500
Mean						4,7	1,8	0,68	8,4	204	1389	177
±s						0,4	1,0	0,86	2,9	204	756	140

The ashing (450 °C) and preparation of plant samples, and dilution of the ash was carried out as described by SILLANPÄÄ (1982). For determinations of P, K, Ca and Mg 8 ml of the main sample solution was diluted to 40 ml with a lanthanum-HCl solution (0,2 M HCl containing 0,31 % La). Ca, K, and Mg were determined with an atomic absorption spectrophotometer using an air-acetylene flame for Ca and Mg and air-propane for K. For determining P colorimetrically by a modified ammonium vanadate-molybdate method (GERICKE and KURMIES 1952), 5 ml of the dilute sample solution and 10 ml of reagent (7,5 g $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$ and 0,38 g NH_4VO_3 in 1 litre of 0,13 M H_2SO_4) were mixed. The colour intensity was measured and compared with appropriate standards (0—70 mg P/l) one hour after mixing. Nitrogen was determined by the Kjeldahl method using Tecator equipment.

RESULTS AND DISCUSSION

Nitrogen. The contents of total soil N at the nine sites average 0,68 ± 0,86 per cent (Table 1). The N contents of the three sites (7, 8 and 9) with organogenic soils exceed those of the other sites considerably. Mainly because of the three high N values the mean is also much higher than for example that (0,288 ± 0,160 %) reported by SILLANPÄÄ (1982) from material consisting almost completely of mineral soils.

The total N contents of soils, however, seem to be relatively poorly reflected by the N contents of various plants. The N content of plants is of special importance nutritionally as it directly reflects their value as a source of protein. In general, compared to other nutrients the variation of the N contents of different plants and plant parts is relatively narrow (Fig. 1). The difference between the lowest and highest mean N contents of plants, turnip rape stalk and pea seed, is only 5,6-fold. Among the macronutrients studied only the variation of phosphorus and in case of micronutrients, (YLÄRANTA and SILLANPÄÄ 1984) that of copper are narrower; 5,5 and 4,2-fold respectively.

The highest N contents were measured in the leguminous crops pea and red clover, and in the tops of the root crops swede and sugar beet (Fig. 1). The second highest N content were found in the seeds of turnip rape. It is therefore of interest to note that the stalk of the same crop shows the lowest N values of the whole material studied. The difference is almost five-fold. Similar differences between the N contents of different parts of the same plants exist in the case of sugar beet (low N roots and high N tops) and to a lesser extent in swede. The differences are 3,4- and 2,1-fold, respectively. A clear dualism can also be observed in grain crops. The grains contain from 1,6 (barley) to 2,3 (rye) times as much N as do the straws.

The above N contents of different plants presented in Fig. 1 may be slightly on the low side especially in case of crops which in practical farming often receive higher doses of N fertilizer. Among others this concerns silage crops which may be fertilized with N rates of up to twice those used in the present study.

Phosphorus. The phosphorus status of the experimental soils at six sites (Table 1) corresponds closely to the mean of the whole country (11,1 mg/l) reported by KURKI (1982). At the remaining three sites (3, 8 and 9) the respective figures are only half of those and thus, the mean of the experimental soils (8,4 mg/l) is somewhat below the national average.

Despite reasonably high phosphorus fertilization (23 kg P/ha), the low soil P status of sites 3, 8 and 9 affects the phosphorus contents of plants by lowering the P mean in 27 out of 31

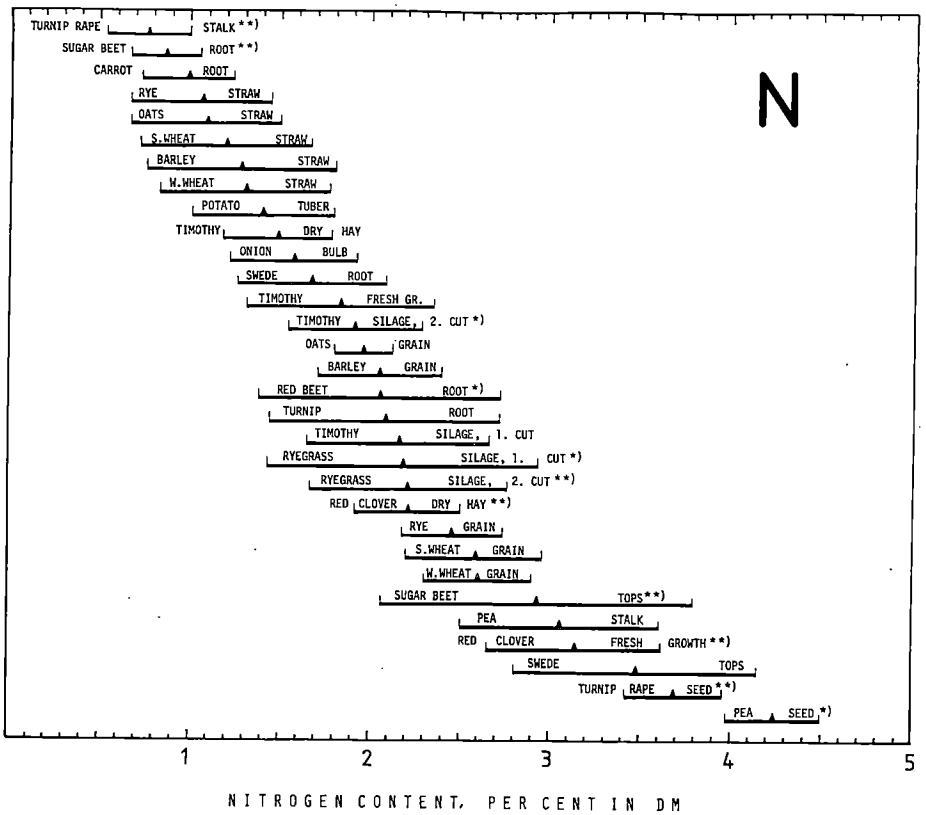

Fig. 1.
Figs 1—5. Two-year averages ($\bar{x}\pm$) of macronutrient contents of different parts of 17 crops grown side by side at nine sites. Crops grown succesfully at eight sites[x)] or at seven sites [xx)] only are indicated in Fig. 1.

cases. In general, the P contents (levels) of different plants in this study do not differ much from those reported earlier from Finnish conditions (e.g. KÄHÄRI and NISSINEN 1978, SYVÄLAHTI and KORKMAN 1978). Internationally, (using wheat as a test crop) the P contents of plants grown in Finnish soils were clearly on the high side among the thirty countries studied (SILLANPÄÄ 1982). This was evidently due to both the relatively high rate of phosphorus fertilization and the high phosphorus status of Finnish soils.

The variation of P contents of different plants is narrower than that of the other four macronutrients in this study (Fig. 2). The highest mean, 0,94 per cent of turnip rape seed exceeds that of the lowest, 0,17 per cent of rye straw, by a factor of only 5,5. The former P contents are exceptionally high compared to those of any other plants or their parts. Obviously, the total P uptake of turnip rape is not much higher than that of other crops but P is mainly concentrated in the seed. In fact, the seeds contain five times as much P as the stalk.

In general, the seeds and grains are typically high in phosphorus while the P contents of different straws are among the very lowest. For the five cereals this difference is 2,0- (oats) to 2,8-fold (rye). The considerable differences in the P contents of the roots of various root crops are worth mention. Sugar beet root contains only 0,18 per cent while the P content of turnip root is 0,43 per cent, on the average. The respective variation of the P contents of

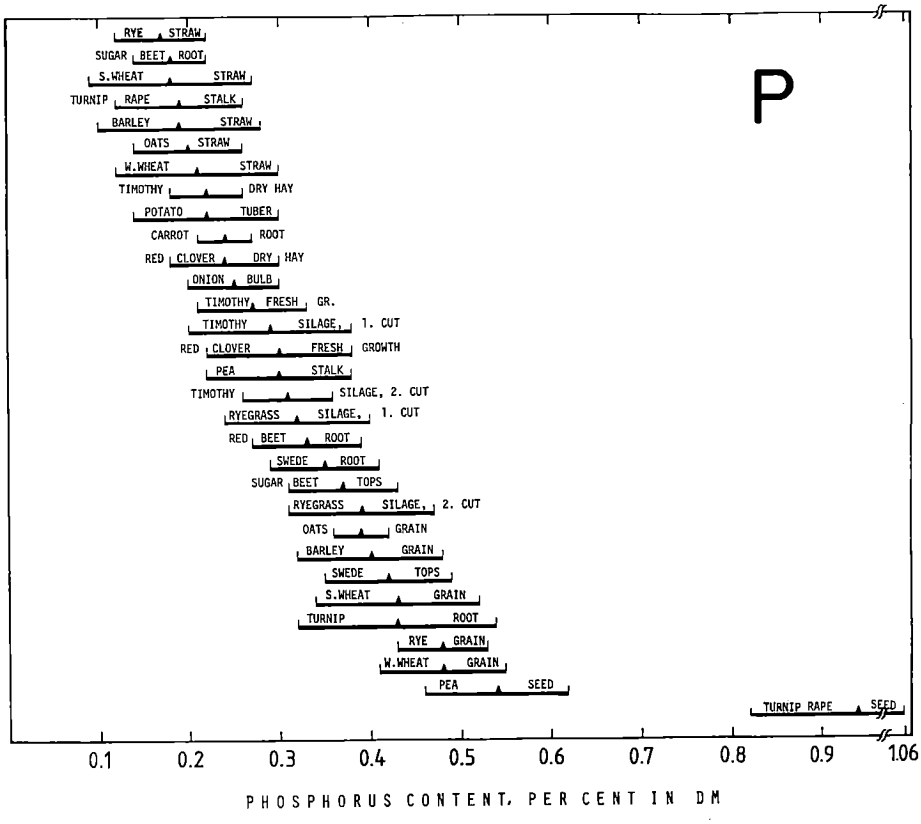

Fig. 2.

grass crops is slightly narrower, from 0,22 (timothy, dry hay) to 0,39 per cent (rye grass, silage, 2. cut).

Potassium. The contents of extractable potassium of the experimental soils correspond quite closely to that of the Finnish soils on the average (148 mg/l, KURKI 1982) if the exceptionally high K soil of Site 5 is excluded (Table 1). As is usual in Finland, the lowest K values of soils were measured in peat soil (Site 7) and in other organogenic soils (Sites 8 and 9). The highest K contents were found in mineral soils of high clay content (Sites 5, 2 and 3).

Soil potassium contents are reflected in the K contents of the vegetative parts of the plants, but not in the seeds or grains. For example, the K contents of the grains of the five cereals and seeds of pea and turnip rape grown on a low K soil at Site 7 were equal or even slightly higher than the K contents of respective plant parts from Site 5 which had an exceptionally high K status. Contrary to this, the K contents of all vegetative plant parts (including all plants and plant parts shown in Fig. 3, except the grains and seeds mentioned) grown at Site 5 were 1,3 — 3,9 (average 2,2) times as rich in K as those from Site 7. Obviously, plants try to maintain a certain K balance in their seeds in spite of the diversity of K soil supplies. Similar results were already presented by SCHREIBER in 1949.

The general variation of the K contents of plants is relatively wide; the highest mean K content (sugar beet tops) being eight times as high as that of the lowest (oats grain). Cereal grains are clearly the group with the lowest K content, usually only 0,4—0,7 per cent. In addition, the variation in K within the grains as well as among different grain species is narrow. The

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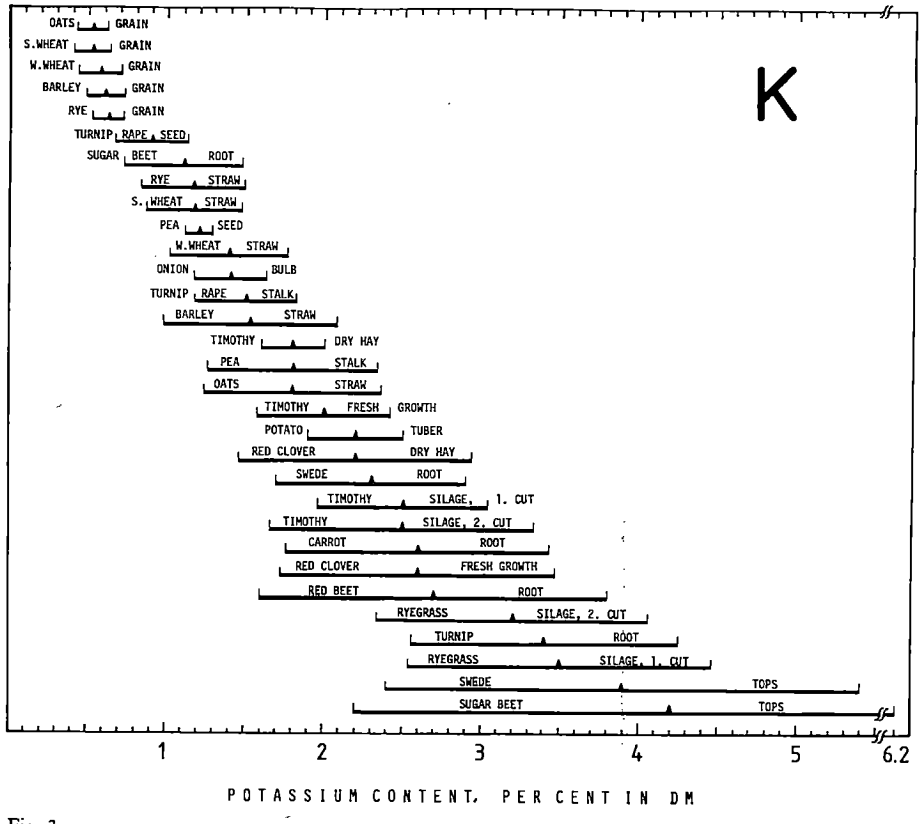

Fig. 3.

straws of the respective crops contain more than twice as much K, often about 1—2 per cent. The highest K contents, around 4 per cent, were measured especially in the tops of root crops. Sugar beet root, however, was an exception with its mean K content of only 1,1 per cent. The latter figure corresponds with the K contents of Finnish sugar beets in general as reported by HALLANORO and HEIMO (1983) which are considered unfavourably high to beet quality.

Grasses are relatively rich in K. However, with exception of rye grass their K contents seldom exceed 3 per cent, which is usually considered as the upper limit for healthy forage (NRC 1980). Thus, for example the K contents of timothy silage average 2,5 per cent which only slightly exceeds the mean (2,4 %) of the large Finnish sample material (2033 samples) reported by KÄHÄRI and NISSINEN (1978). Heavy potassium or nitrogen fertilization may raise the K content of grasses up to a four per cent level (SILLANPÄÄ 1985, SILLANPÄÄ and RINNE 1975).

Calcium. The content of acid ammonium acetate extractable calcium of the nine experimental soils averages 1389 mg/l (Table 1) which is slightly higher than in the general inventory of agricultural soils (1282 mg/l) reported by SIPPOLA and TARES (1978) but lower than the average of the over 600 000 soils (1434 mg/l) analysed by the Soil Testing Service during 1976—80 (KURKI 1982). The variation of soil Ca in this material also resembles those of the above larger studies. The effect of the Ca status of soils can also be seen in the Ca contents of plants. For example, all plants and their parts from Site 9 with the highest Ca soil

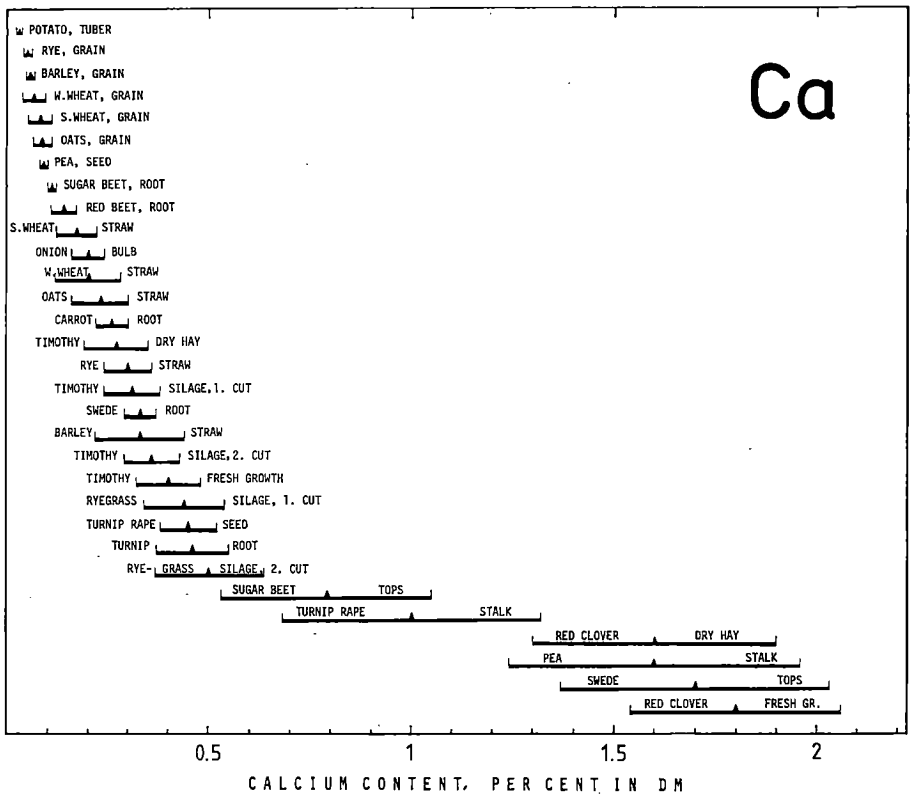

Fig. 4.

have higher Ca contents than those grown on the soil poorest in Ca (Site 3).

Differences between the Ca contents of various crops and their parts are greater than those of any other macronutrient studied (Fig. 4). Thus the highest mean Ca content measured in red clover (fresh growth) was sixty times as high as the lowest mean found in potato tuber. Beside red clover, swede tops and pea stalk were exceptionally rich in Ca. Grasses usually have a medium high Ca content while cereal grains and pea seed are very poor in it. Somewhat higher Ca contents were found in cereal straws and in the underground parts of the root crops. The concentration of Ca in certain parts of the plant was quite pronounced. For example in root crops, sugar beet and swede, the tops contained 5—7 times as much Ca as their roots. However the difference was most pronounced in pea, the stalk of which was 18 times as rich in Ca as the seed.

Magnesium. The average acid ammonium acetate extractable Mg content and standard deviation (177 ± 140 mg/l, Table 1) of the experimental soils are almost identical to those (178 ± 150 mg/l) reported by SIPPOLA and TARES (1978) from a much larger quantity of ($n > 2000$) Finnish soil material and only slightly lower than the average (189 mg/l) of all the soils analysed by the Soil Testing Service during 1976—80 (KURKI 1982). Thus in respect of Mg the experimental conditions are quite typical to Finland where the soils are generally low in Mg by international standards (SILLANPÄÄ 1982).

The acid ammonium acetate extractable soil magnesium contents vary considerably from one experimental site to another (Table 1) as

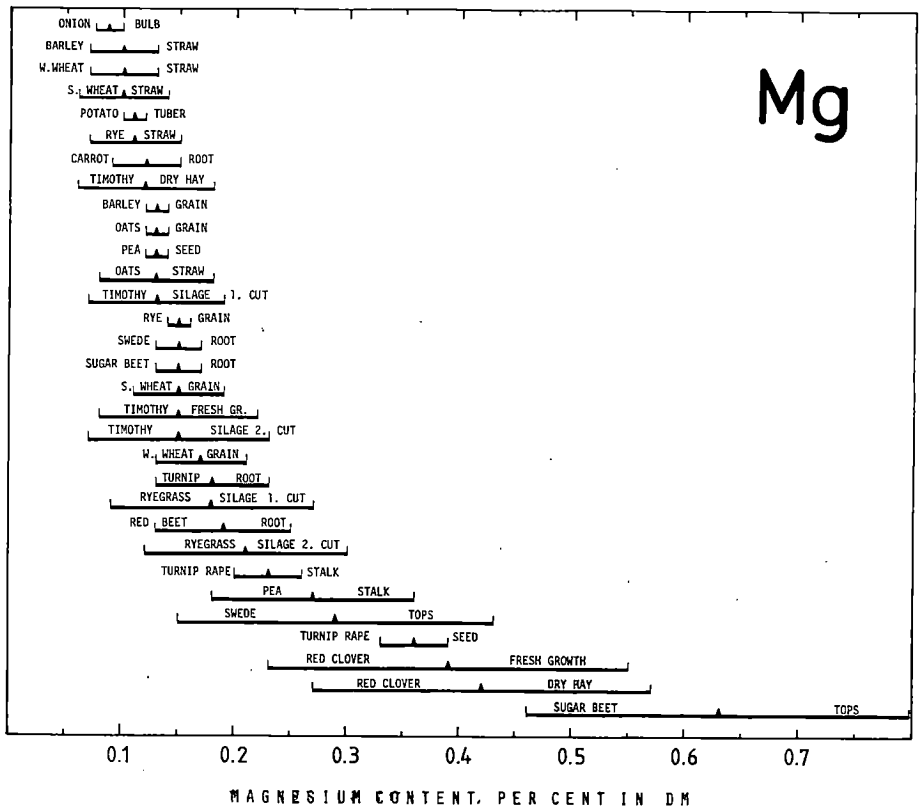

Fig. 5.

also reflected in the Mg contents of plants. Thus the Mg contents of plants grown on the highest Mg soil at Site 9 are almost twice (average 1,91 times) as high in Mg as those grown on Mg-poor soil at Site 6. These differences are especially pronounced in the Mg contents of the vegetative parts of the plants. For example, the straws of the five cereal crops from Site 9 contain 2,2—3,4 (average 2,8) times as much Mg as those from Site 6. In respective grains these differences are only from 1,1- to 1,4-fold (average 1,2).

The relative concentrations of Mg in different crops resemble those of Ca (Figs 4 and 5). Therefore as in the case of Ca the highest Mg contents were measured in sugar beet and swede tops, red clover and pea stalk. Turnip rape seed and stalk were also quite rich in both of these elements. The group of the lowest Mg (and Ca) contents consist mainly of onion, potato tubers, and the straws and grains of the cereal crops. Contrary to Ca the Mg contents of grains are somewhat higher than those of the straws. The roots of carrot, swede and sugar beet are quite low in Mg (and Ca) while most of the grasses have medium high contents of these nutrients.

Because of the relatively narrow variation of Mg contents (the highest mean exceeds the lowest by a factor of 7) compared to that of Ca the Ca/Mg ratio is subject to considerable variation. In the crops having the highest Ca contents (red clover, swede tops, pea stalk) the ratio varies between 4 and 6 while in the low Ca crops (all grains, potato, pea seed and the roots of sugar beet and red beet) the Ca/Mg ratio is less than 1. In most other crops it is between 2 and 3.

The differences between the Mg contents of different parts of the same plants (e.g. those of pea, sugar beet, swede) are to the same direction as those between their Ca contents but not as pronounced.

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SELOSTUS

Viljelykasvien pääravinnepitoisuuksien vertailu

HÅKAN JANSSON, TOIVO YLÄRANTA ja MIKKO SILLANPÄÄ

Maatalouden tutkimuskeskus

Viljelykasvien lannoitustarve arvioidaan yleensä maa-analyysin perusteella. Kasvien ravinnetarve heijastuu myös niiden maasta ottamissa erilaisissa ravinnemäärissä. Lisäksi ihmisten ja eläinten ravitsemuksen kannalta on tärkeää tuntea ne mahdollisuudet, joilla kasvin valinnalla voidaan vaikuttaa ruoan tai rehun kivennäisainepitoisuuksiin.

Tällä tutkimuksella pyrittiin saamaan vertailukelpoista tietoa suomalaisissa oloissa kasvaneiden eri viljelykasvien pääravinnepitoisuuksista. Yhdeksällä, eri puolilla Suomea sijaitsevalla koepaikalla kasvatettiin 17 viljelykasvia ja niiden pääravinnepitoisuudet analysoitiin.

Eri kasvien kuiva-aineen suurimmat keskimääräiset typpi-, fosfori-, kalium ja magnesiumpitoisuudet olivat 5—8 -kertaisia alimpiin keskipitoisuuksiin verrattuna. Vastaava vaihtelu kalsiumpitoisuuksissa oli 60 -kertainen.

Viljojen jyvät sisälsivät yleensä runsaasti fosforia, kohtalaisesti typpeä ja magnesiumia, mutta olivat kalium- ja kalsiumköyhiä. Olkien typpi-, fosfori- ja magnesiumpitoisuudet olivat alhaisia, mutta niiden kalium- ja kalsiumpitoisuudet keskitasoa. Sipulin ja perunan mukuloiden todettiin sisältävän niukasti pääravinteita. Heinäkasveissa pääravinteita oli vähän keskimääräistä enemmän.

Palkokasvien typpi-, kalsium- ja magnesiumpitoisuudet olivat yleensä korkeampia kuin muiden kasvien, mutta fosfori- ja kaliumpitoisuudet keskimääräistä tasoa. Tästä linjasta poikkesivat herneen siemenet. Niissä oli fosforia runsaasti, mutta vähän kalsiumia, magnesiumia ja kaliumia.

Juurikasveille tyypillistä oli pääravinteiden esiintyminen korkeina pitoisuuksina naateissa, kun taas juurissa niitä oli joskus hyvinkin niukasti. Eri kasvinosien välisiä eroja todettiin myös rypsillä, jolla erityisesti typpi ja fosfori olivat kerääntyneet siemeniin varren pitoisuuksien jäädessä erittäin alhaisiksi.

ANNALES AGRICULTURAE FENNIAE, VOL. 24: 149—160 (1985)
Seria AGRICULTURA N. 74 — Sarja PELTOVILJELY n:o 74

PRODUCTION OF HAPLOIDS FROM ANTHER CULTURE IN AGRICULTURALLY VALUABLE *BRASSICA CAMPESTRIS* L. CULTIVARS

SEPPO SORVARI

SORVARI, S. 1985. **Production of haploids from anther culture in agriculturally valuable *Brassica campestris* L. cultivars.** Ann. Agric. Fenn. 24: 149—160. (Agric. Res. Centre, Dept. Pl. Breed. SF-31600 Jokioinen, Finland.)

Anthers from varieties, lines and crosses of *Brassica campestris* spp. oleifera adapted to northern latitudes were isolated and induced to produce haploids. As expected very high genotypic differences were recorded. In comparing the mean embryoid production of F_1's in various types of crosses the highest regeneration rate was obtained in the cross type "dihaploid x dihaploid". The second highest was recorded in the F_1's originating from varieties and lines crossed with each other.

The number of haploids regenerated from donor plants with high-glucosinolate content was about twice as high as that from donor plants with low glucosinolate content, but addition of extract with high glucosinolate content in the nutrient medium had an inhibitory effect on the mean embryoid production.

Index words: *Brassica campestris,* summer turnip rape, anther culture, haploids, glucosinolates, seed extract, androgenesis, embryogenesis.

INTRODUCTION

Brassica campestris L. spp. oleifera (Metzg.) is in the marginal cultivation areas one of the most important oilcrops. As a relatively new crop plant in the northern latitude breeding work has to meet high demands. The oil should have high nutritional quality with low content of erucic acid (C22:1) and high content of linoleic acid (C18:2). A low content of linolenic acid (C18:3) is desirable to avoid problems in refining due to polyunsaturation (JÖNSSÖN 1973).

Flours prepared from meal after oil extraction contain 30—50 % protein with high quality amino acid composition (FINLAYSON 1977). Harmful effects of hydrolysis products of glucosinolates in rapeseed meal, however, restrict its use in non-ruminant feed (BOWLAND et al. 1963). Glucosinolate content should be reduced below 30 umol in 1 g fat free meal without lowering the yield capacity.

These are only few aspects that should be improved in *B. campestris* cultivars. In

conventional breeding work much progress has been achieved e.g. in lowering the erucic acid and glucosinolate content. (DOWNEY and HARVEY 1963, DORREL and DOWNEY 1964, LEIN 1970, VAN ETTEN et al. 1974, MCGREGOR and DOWNEY 1975). Because of the self-incompatible nature of *B. campestris* there is great need to study the possibilities for producing homozygous, dihaploid lines via anther culture in order to accelerate the breeding process.

In the last 15 years it has been shown that the artificial production of haploids via anther culture can be carried out in *B. campestris* (WANG and CHANG 1975, KELLER et al. 1975, KELLER and ARMSTRONG 1979) in *B. oleracea* (KAMEYA and HINATA 1970, KELLER and ARMSTRONG 1981) in *B. napus* (THOMAS and WENZEL 1975, KELLER and ARMSTRONG 1977, WENZEL et al. 1977, KELLER and ARMSTRONG 1978).

Homozygous plant material with high variability is very valuable in plant breeding. In this paper the investigations on haploid production via anther culture in agricultural important *B. campestris* varieties are described.

MATERIAL AND METHODS

Donor plants

The donor plants (Table 1) were derived from Scandinavian and Canadian cultivars and sarson varieties. The line Sv 03202 ('Ante') was kindly supplied by Dr Gösta Olsson in Svalöv AB in Sweden. 'Torch', 'Span' and 'Candle' are commercially available varieties of Canadian origin. Jo 3100, Jo 3101 and Jo 3089 are lines from the Department of Plant Breeding in Jokioinen, Finland. Sarson varieties were kindly supplied by Mr. George A. White in Beltswille Agricultural Research Center, Maryland and R-500 by Canada Agricultural Research Station Saskatoon.

Table 1. List of the varieties and lines used in the anther culture experiments.

variety/line	type*	variety/line	type*
Torch	0	Jo 3100	00
Span	0	Jo 3101	00
Candle	00	Jo 3089	00
DF-15	00	R-500	++
Ante	00	Sarson var. lines	++

* 0 = low erucic[1] and high glucosinolate content
00 = low erucic and low glucosinolate [2] content
++ = high erucic and high glucosinolate content

1) low erucic = erucic acid content < 5 % in total fatty acid content
2) low glucosinolate = glucosinolate content < 30 umol in 1 g fat free meal

The fatty acid compositon of the material was analyzed with gas chromatography using the half seed technique (DOWNEY and HARVEY 1963, THIES 1971). Except for experiment with sarson material only seeds without erucic acid were selected.

The glucosinolate content was analyzed with gas chromatography according to THIES (1977, 1980). For a rough estimation of glucosinolate content the "tape test" (Tes-Tape, Eli Lilly and Co) was utilized. In order to detect myrosinase defective seeds myrosinase was added. Myrosinase was prepared according to SCHWIMMER (1961).

Growth conditions for donor plants

Donor plants were grown in greenhouse and growth chambers. The growth conditions are shown in Table 2.

Plants were grown in fertilized peat. Once a week plants were fertilized with N-P-K-B fertilizer (16-7-13-0,2). At the end of the first and second week dolomite lime about 5 g/pot was added.

Table 2. Growth conditions of donor plants in the greenhouse and growth chamber.

	Green house	Growth chamber
Lamps in one illumination unit	2	1
Type of lamps in one unit	1 high pressure sodium Airam SNAT 400 W high pressure merc ry Airam HQJ 400 W	1 metal halide Osram Power Star HQJ-T 1000 W/D
Power consumed per unit	2 x 400 W	1 x 1000 W
Units per 1 m^2 growth area	1	1
Day length	18 h	18 h
Temperature in the day	22 °C	20 °C
Temperature in the night	19 °C	15 °C
Rel. humidity (day/night)	85 %	90 %
Lx (1 m from the source)	10 klux	50 klux

Isolation and cultivation of anthers, embryoids and anther derived plants

Buds were harvested from approximately 4 week old donor plants before stem elongation and flower emergence (KELLER et al. 1975). The isolation of the anthers was done at the uninucleate stage of microspores. The length of the buds at that time was 3±1 mm. Only the main inflorescence prior to stem elongation was used (KELLER et al. 1975). Buds were sterilized with sodium hypochlorite (5 %) for 15 min and rinsed once with sterile demineralized water. For the excision of anthers, buds were cut in the side of the receptacle at the height of the filaments, and anthers were pressed out gently. Depending on the donor plant material, 1000—2000 anthers could be isolated daily and transferred in to the nutrient medium.

In the first phase anthers were incubated in B51 medium (Table 3) developed by GAMBORG et al. (1968) and modified by KELLER et al. (1975) and KELLER and ARMSTRONG (1979). Pyridoxine-HCl (1 mg/l) was added and iron was added as Fe-EDTA according to MURASHIGE and SKOOG (1962). In this medium anthers were incubated in the dark, first at 35 °C for 24 hours (KELLER and ARMSTRONG 1979) and then at 25 °C for 7 days.

After the dark treatment the anthers were transferred from the B5I into B5II medium (Table 3) with low sucrose content. The petri

Table 3. Nutrient media utilized in anther and embryo culture (expressed in mg/l nutrient medium. Sucrose and agar are given in % w/v).
CAMBORG et al. (1968), KELLER et al. (1975), KELLER and ARMSTRONG (1979) and MURASHIGE and SKOOG (1962)

	B51	B5II	B5III	MSIII
KNO_3	2500	2500	2500	1900
$(NH_4)_2SO_4$	134	134	134	-
$NaH_2PO_4 \times H_2O$	150	150	150	-
$CaCl_2 \times 2H_2O$	750	750	750	440
$MgSO_4 \times 7H_2O$	250	250	250	370
NH_4NO_3	-	-	-	1650
KH_2PO_4	-	-	-	170
$MnSO_4 \times 4H_2O$	7,6	7,6	7,6	22,3
H_3BO_3	3,0	3,0	3,0	6,2
$ZnSO_4 \times 7H_2O$	2,0	2,0	2,0	8,6
KJ	0,75	0,75	0,75	0,83
$Na_2MoO_4 \times 2H_2O$	0,25	0,25	0,25	0,25
$CuSO_4 \times 5H_2O$	0,025	0,025	0,025	0,025
$CoCl_2 \times 6H_2O$	0,025	0,025	0,025	0,025
$FeSO_4 \times 7H_2O$*	27,8	27,8	27,8	27,8
Na-EDTA *	37,3	37,3	37,3	37,3
Nicotinic acid	1,0	1,0	1,0	0,5
Thiamine HCl	10,0	10,0	10,0	0,5
Pyridoxine HCl	1,0	1,0	1,0	0,5
m-Inositol	100,0	100,0	100,0	100,0
Glycine	-	-	-	2,0
NAA	0,1	0,01	-	0,2
2,4-D	0,1	0,01	-	
GA_3	-	0,5	-	1,0
BAP	-	1,5	-	1,0
Glutamine	800,0	800,0	800,0	800,0
Serine	100,0	100,0	100,0	100,0
Sucrose	10 %	2 %	2 %	2 %
Agar (Difco Noble)	0,8 %	0,8 %	0,8 %	0,8 %
pH	5,8	5,8	5,8	5,8

* Preparing Fe-EDTA solution see MURASHIGE and SKOOG (1962)

Fig. 1. Cloned and potted anther culture derived plants in small (∅ 50 mm) pots.

dishes were put under low intensity fluorescent light (3000 lux) with 18 h day at 25 °C. Emerging embryoids were harvested weekly and transferred into hormone free B5III or modified MS (=MSIII) medium (Table 3) and cultured as previously mentioned.

Plants were cloned during the *in vitro* stage and after root formation they were stored in test tubes in semi dark at 3 °C for other experiments. Only axillary buds and apical meristems were used. Representatives with vigorous root system were taken from the clones and potted into the 5 cm pots with a mixture of 1/3 sand and 2/3 fertilized peat (Fig. 1). The potted plants were kept in the growth chamber for 10 days. The growth conditions in the chamber were set at 90 % RH, 18 h day and 20 °C/15 °C (day/night).

The ploidy of the plants was determined by looking at the root tips. Root tips were kept in ice water over night, fixed in ethanol: acetic acid (3:1), stained with acetic orcein and evaluated immediately. Diploidization of monohaploids was made with colchicine (0,1 % + 1 % DMSO) by injecting the solution directly into axillary buds (HOFFMAN et al. 1982).

The experiment with seed extracts

Extracts were prepared from varieties with high glucosinolate content. Extract NrI was prepared as follows: 20 g dry seeds were pulverized in an electric coffee grinder. The powder was soaked 10 min in 200 ml distilled water and extracted by boiling for 1 h. The extract was filtered and distilled water was added to make 200 ml.

Extract NrII was prepared in the same way as NrI, but myrosinase was inactivated by keeping the intact seeds in a 95 °C water bath for 20 min. The seeds were dried over night at 60 °C before pulverizing. The extracts NrI and NrII were added 50 ml/l nutrient medium.

In order to avoid variations due to genotypic differences, anthers from a single bud and donor plant were treated with extracts I and II.

The response of high and low glucosinolate types in androgenesis

The androgenetic response of donor plants with high or low glucosinolate content was studied by dividing the donor plant material into two groups:

group I: glucosinolates < 30 umol/lg fat free meal

group II: glucosinolates > 30 umol/lg fat free meal

The androgenesis in varieties, lines and crossings

From the embryoid production in various donor plant types (DPT) six groups were formed: DPT 1. varieties and lines, DPT 2. varieties as female crossed with dihaploid A_1-plants, DPT 3. dihaploid A_1-plants as female crossed with varieties or lines, DPT 4. dihaploid A_1-plants crossed with each other, DPT 5. varieties or lines crossed with each other and DPT 6. dihaploid A_2-plants.

For the DPTs 2—5 only F_1-seeds were used. The varieties and lines in DPT 1 were F_n generations. Dihaploid plants used as DPT 6, were grown from the seeds of A_1 plants.

RESULTS

Plant formation in anther culture occurred via embryogenesis (Figs 2 and 3). Callus formation was seldom recorded. If callus was formed the regeneration of shoots in callus was not successful but differentiation of roots took place. Chlorophyll deficient plants were never recorded. In each case the formation of embryoids was mostly concentrated on one or few anthers. In addition to genotypic differences there are differences in response between anthers of a donor plant or even a single bud.

The highest mean value, 106 embryoids per 1000 isolated anthers, was recorded with the bud size of 3 mm (Table 4). This size is correlated to the uninucleate stage of microspores. The second best mean value 43/1000 was reached with the bud size of 4 mm. This correlates to late uninucleate stage or first mitosis.

The bud size of 2 mm corresponds to tetrad stage or very early uninucleate stage. The anther response in this stage was low (0,8/1000). The anthers isolated from 5 mm buds (binucleate stage) gave no response in anther culture.

Frequency of embryoid formation fluctuated throughout the year. The highest mean embryoid values were reached in March (64,5/1000), June (66,0/1000), September (53,0/1000) and November (63,2/1000) (Fig. 7). Unfortunately the isolation of anthers in February and December was not succesful and reliable results from these months are not available. Spring and autumn seems to be better seasons for the anther culture than summer and winter. The differences between growth chambers and greenhouses are not studied.

Table 4. Effect of the bud size on the embryoid formation in anther culture.

size of the bud in mm	numbers of plated anthers	number of embryoids	number of embryoids in o/oo
2	1296	1	0,8
3	1368	145	106,0
4	1108	48	43,0
5	90	-	0,0

Fig. 2. Anther with one well developed embryoid 20 days after inoculation.

Fig. 3. Masses of embryoids emerging from one anther.

Embryoid formation in low-glucosinolate types was 12,0/1000 and in high-glucosinolate types 29,4/1000 (Table 5). The number of embryoids per induced anther was in both cases about two. In the high-glucosinolate types the number of embryoid forming anthers is higher (14,5/1000) resulting in higher embryoid production than in low-glucosinolate types.

The stability of the embryoids seems to depend on the donor plant type. The amount of haploids (Fig. 4) derived from the high-glucosinolate types was about two times higher from the low glucosinolate types.

When using high-glucosinolate donor plants the number of haploids in 380 analyzed plants

Table 5. Embryoid formation in the anthers dissected from the buds of donor plants with high and low glucosinolate content.

glucosinolate content in 1 g fat free meal	numbers of plated anthers	numbers of androgenic anthers	numbers of androgenic anthers in o/oo	numbers of embryoids	numbers of embryoids in o/oo
< 30 umol	16937	91	5,4	207	12,0
> 30 umol	8979	130	14,5	264	29,4

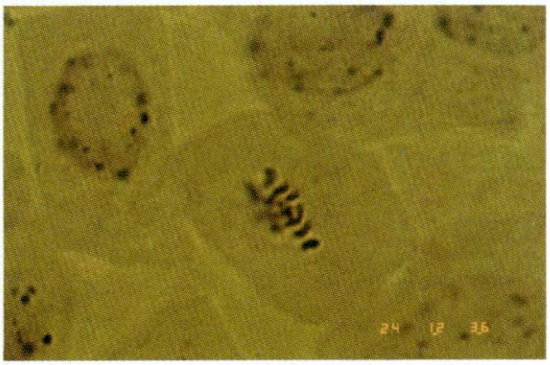

Fig. 4. Root-tip squash of the microspore originated plant with haploid (ln = 10) chromosome set.

was 264 (69,5 %) and diploids or higher ploids 116 (30,5 %). Low-glucosinolate containing donor plants produced 329 (36,6 %) haploids and 570 (63,4 %) diploids or higher ploids from 899 culture derived plants analyzed (Table 6).

Adding seed extract to the nutrient medium did not enhance the mean embryoid formation (Table 7). In the control and in extract I and II the number of embryoid forming anthers was 13/1000.

Embryoid production was 38/1000 in the control 19/1000 in extract I and 28/1000 in extract II. Addition of the extract to the

Table 6. The distribution of haploids and higher ploids among embryoids originated from donor plants with high and low glucosinolate content.

clucosinolate content in	numbers of	haploids		diploids or higher ploids	
1 g fat free meal	analyses	number	in %	number	in %
< 30 umol	899	329	36,6	570	63,4
> 30 umol	380	264	69,5	116	30,5

nutrient medium depressed the mean embryoid formation. Nutrient medium with seed extract I (hydrolysed glucosinolates) depressed embryoid production even more than extract II with nonhydrolysed glucosinolates.

Donor plant types classified according to the cross and origin gave highly different androgenetic responses in anther cultures (Table 8). The best response was achieved in the DPT 4 (A_1 x A_1) with a mean embryoid number of 118/1000. DPT 5, where normal varieties or lines where crossed with each other, resulted in a mean embryoid number of 79/1000.

In spite of anther culture derived pollinator the response of DPT 2 was still 10/1000 lower than the response of DPT 1. Because parents for different DPTs were selected randomly it is possible that combinations of parents for DPT

Table 7. The effect of seed extract with hydrolyzed (extract I) and nonhydrolyzed (extract II) glucosinolates on the embryoid formation in anther culture.

type of treatment	numbers of plated anthers	numbers of androgenic anthers	numbers of androgenic anthers in o/oo	numbers of embryoids	numbers of embryoids in o/oo
control	4987	76	15	189	38
control + extract I	4492	57	13	85	19
control + extract II	4486	60	13	128	28

Table 8. Androgenetic response of different donor plant types (DPT) in anther culture. Classification after mode of crossing.

Donor plant type (DPT)	generation used for plating	number of plated anthers	number of androgenic anthers	number of androgenic anthers in o/oo	number of embryoids	number of embryoids in o/oo
1. variety or line	F_n	14983	169	11	344	23
2. variety or line × dihaploid A_1	F_1	2529	19	8	33	13
3. dihaploid A_1 × variety or line	F_1	9709	194	20	572	59
4. dihaploid A_1 × dihaploid A_1	F_1	4428	122	28	524	118
5. variety or line × variety or line	F_1	2508	55	22	199	79
6. dihaploid	A_2	1666	15	9	35	21

2 were non optimal, resulting in a reduced response in anther cultures.

Dihaploid A_2 donor plants (DPT 6) gave a lower response (21/1000) in anther culture than DPT 1 (normal varieties or lines). This is not surprising since mono- and dihaploids show substantial loss of fitnes and vigour. Symptoms are similar to those of inbreeding depression. In mono- and dihaploids this is expressed as tender growth habits, reduced number of flower buds, tendency to protogyny and low seed set.

DISCUSSION

Microspore staging

Morphologically the microspore staging is difficult. SOPORY and MAHESHWARI (1976) indicated that in *Datura innoxia* bud size alone is not a reliable criterion for estimating the developmental stage of microspores.

In practical work it is not possible to determine the developmental stage of microspores in every bud. The time used for staging can easily be compensated by isolating more anthers and standardizing growth conditions of donor plants.

Two factors should be considered when bud morphology is used for staging *B. campestris*. First, the harvest took place when the biggest bud in the main inflorescence reached 4—5 mm. At that time the age of the donor plants was about 4 weeks. Increasing age of the donor plants seems to shorten the optimal period for isolation of anthers at the correct stage. Second the buds were dissected only from the main inflorescence before stem elongation. In the side inflorescences, after stem elongation, the correlation between floral bud morphology and optimal dissecting stage can vary.

Under standardized conditions only the buds between 2 mm and 4 mm gave an androgenetic response in anther culture. Highest response was reached in the phase that correlates with the uninucleate stage of microspores.

Anthers from buds 2 mm or smaller had soft texture and were difficult to transfer without damaging. Buds bigger than 4 mm contained anthers in binucleate stage. These anthers had a solid texture and the colour was turning yellow. Sterile isolation of anthers in this stage was rather difficult because the sepals were less tightly closed than in earlier stages.

Seasonal effects

SUNDERLAND (1974) indicated that anther response varied greatly in greenhouse grown *D. innoxia* and *Nicotiana tabacum*. In anther cultures of *B. campestris* seasonal variation

could also be observed. Possibly environmental conditions like temperature, daylength and light intensity are optimal in spring and autumn. Why such fluctuations occur in the culture of anthers from donor plants grown in growth chambers is difficult to elucidate without making a close study of working methods and other related factors. In *B. campestris* a high light intensity with long days and cool temperatures (below 20 °C) produces vigorously growing donor plant material with good anther culture response.

Temperature treatment

One essential factor for the embryoid formation in anther culture is temperature treatment at 35 °C. According to KELLER et al. (1975) no haploids among regenerated plants were found when anthers were treated at 25 °C. The androgenetic response at this temperature was considerably reduced.

The temperature treatment enhances embryoid production and increases the number of haploids from them (KELLER and ARMSTONG 1979). Keller and Armstrong used the high-glucosinolate cultivars 'Torch' and yellow seeded "R500" with the glucosinolate content > 30 umol/g fat free meal. The number of haploids derived from the microspores of our high-glucosinolate containing donor plant types (69,5 %) are comparable with Keller's (74 %).

Role of glucosinolates

Donor plant types with low-glucosinolate content behave differently in anther culture than those with high-glucosinolate content. The mean number of embryoids in low-glucosinolate types was 12/1000 and in high-glucosinolate types 29,4/1000. The number of haploids regenerated from low glucosinolate types was 36,6 %. The number of haploids and diploids or higher ploids is reverse compared to the regenerated plants in anther culture of high-glucosinolate donor plant types.

Embryoids and plants regenerated in the anther culture of low glucosinolate donor plant types had more frequent aberrations in growth and differentiation than those from high glucosinolate types. The genes responsible for glucosinolate metabolism might be closely linked with the genes controlling differentiation. Another possible reason for the aberrations could be the increased sensitivity of the low-glucosinolate types to the auxins added to the nutrient medium. Higher spontaneous diploidization of the embryoids derived from the microspores of the low-glucosinolate donor plant type could also be due to changes in microspore response following selection procedures.

Because the high glucosinolate donor plant types gave a better response than the low-glucosinolate ones the effects of seed extracts made from high-glucosinolate containing seeds were studied. Among the glucosinolates the cleavage products of glucobrassicin (3-indolymethyl-glucosinolate) has been postulated to have auxin activity (ANDERSEN and MUIR 1966). In acid conditions glucobrassicin is hydrolysed by myrosinase (thioglucosid glucohydrolase E.C. 3.2.3.1.) to indole-3-acetonitrile (IAN). It is not clear if IAN is first converted to indol-3-acetic acid (IAA) by nitrilase (BALLIN 1962).

The non-heat-treated extracts, where glucosinolates were hydrolyzed by myrosinase, showed stronger inhibitory effect (embryoid formation 19/1000) than heat treated extract (embryoid formation 28/1000). The content of glucobrassicin in *B. campestris* seeds is very low. In experiments where auxin-like activity of IAN could be found, very high concentrations were used (ANDERSEN and MUIR 1966). This does not agree with the definition of the hormones. However, some genotypes showed response only on extract I or II, so in the recalcitrant genotypes the use of seed extracts can be profitable. Because donor plants with high glucosinolate content are often very vital

it seems more probable that the loss of vitality via selection is one of the factors depressing the embryoid formation in anther culture.

Hybrid vigour

A_1-donor plants of self-fertile species seem to behave differently in anther culture. PICARD and DE BUYSER (1977) showed that in wheat A_1 responded better in anther culture than parental lines, but F_1 hybrids of dihaploids responded even better. A very interesting point in *B. campestris* could be recorded when pollinating sarson material with other cultivars (e.g. 'Torch'). F_1 showed very stark hybrid vigour that was in F_1-seeds visible as "giant" seeds with up to four times higher thousand seed weight as normally and very high seed set in F_1-generation. Such material was sometimes extremly productive in anther culture. In present situation hybrid vigour seems to be an important factor in success of anther culture but it can be assumed that it is not the primary factor but rather reflecting the nonoptimal cultural conditions.

Secreting tapetum

There is probably one highly specific stage where not only the developmental stage of microspores but also the maturity level of tapetum have a decisive effect on androgenesis. Tapetum has cell division promoting effect in the initial steps of androgenesis, and embryoid formation can start also in the vicinity of the anther (Fig. 5). Metabolites needed in some early steps of embryogenesis are obviously secrected by the tapetum. The probable existence of tapetal factors have been suggested also in *Hyoscyamus niger* and *N. tabacum* (RAGHAVAN 1978, SUNDERLAND and ROBERTS 1979).

If embryogenesis is induced by the tapetum, this specific stage must be synchronous with the embryogenetic induction responding stage of microspores (MEIRS). The tapetal embryogenesis inducing stage (TEIS) and MEIRS have maybe a short duration, resulting in maximum synchrony of both being achieved in only a few genotypes. This would explain why all four (six) anthers of a bud dont respond simultaneously when cultured. Specific growth conditions *in vivo* could have a synchronizing effect on TEIS and MEIRS. Without exact knowledge of the regulation of embryogenesis, various treatments have limited value in androgenesis, probably because the various genotypes respond in a characteristic manner to different growth conditions and pre treatments.

The application field of the homozygotization process can be very large. Monohaploids can be used for other biotechnological purposes as well. In anther cultures, the enhancement of

Fig. 5. Well developed embryoids growing in the vicinity of the anther.

Fig. 6. Secondary embryoid formation in epidermis of 8 weeks old microspore originated plantlet.

variability (Fig. 6) for plant breeding purposes is valuable if combined with direct homozygotization. This is important in the breeding of *B. campestris,* where the genetic base, due to strict selection, has become very narrow in recent years.

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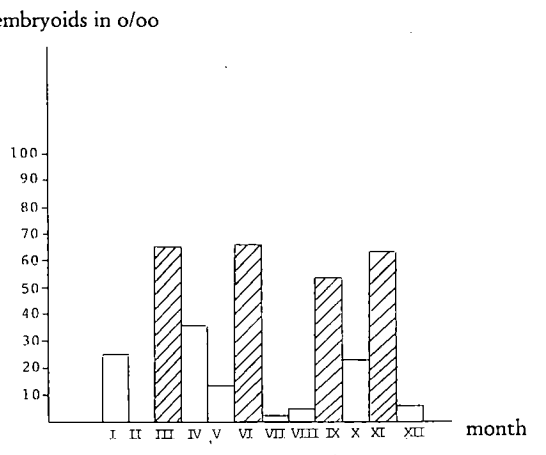

Figure 7. Mean embryoid formation in anther culture during the year

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SELOSTUS

Haploidien tuottaminen kevätrypsin ponsiviljelmien avulla

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Maatalouden tutkimuskeskus

Rypsin epäkypsät siitepölyhiukkaset (mikrospoorit) voidaan indusoida steriilissä solukkoviljelmässä suoraan alkionmuodostukseen (embryogeneesiin). Näistä n.k. embryoideista voidaan kasvattaa kasviyksilöitä, joilla on täten sama määrä kromosomeja kuin sukusoluilla. Ne ovat haploideja. Käsittelemällä haploidit syysmyrkkyliljasta saatavalla alkaloidilla, kolkkisiinilla, voidaan kromosomien määrä palauttaa jälleen diploidiksi. Näin saadaan diploideja, hedelmöityskelpoisia ja homotsygootteja yksilöitä.

Siitepölyhiukkasen partenogeneettiseen kehitykseen suoraan kasviksi (androgeneesiin) vaikuttavat useat tekijät. Tärkeimpiä näistä ovat genotyyppi, lähtömateriaalin kasvatusolosuhteet ja solukkoviljelyolosuhteet. Olennaisia seikkoja solukkoviljelyolosuhteissa ovat yhden vuorokauden kestävä lämpökäsittely +35 °C:ssa heti ponsien eristyksen jälkeen ja korkea ravintoalustan sokeripitoisuus koko induktiovaiheen ajan.

Menetelmän avulla voidaan tuottaa homotsygoottia materiaalia siemenestä siemeneen alle vuodessa. Soveltamalla yhteen sekä haploidien tuotanto että solukkoviljelmissä luontaisesti esiintyvä voimakas vaihtelu, voidaan ponsiviljelmien avulla tuottaa homotsygoottia runsaasti vaihtelevaa materiaalia. Tämä on tärkeää, koska rypsimateriaalin geneettinen perusta on viime vuosina runsaan valinnan vuoksi käynyt varsin kapeaksi.

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Review article

RESISTANCE OF INSECTS AND MITES TO PESTICIDES IN FINLAND

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The first cases of pest resistance to insecticides occurred in Finland in the beginning of the 1950's. It was the resistance in houseflies *Musca domestica* to DDT. Since then, the most extensive resistance to DDT, lindane, cyclodienes, organophosphates, pyrethrin and pyrethroids has been detected in houseflies. In addition, *Blattella germanica* has developed a slight resistance to dieldrin and *Tribolium confusum* to phosphine and methyl bromide.

In greenhouses, *Myzus persicae* has been found to be resistant to organophosphates and lindane, while *Tetranychus urticae* has been found to be resistant to organophosphates and aldicarb. In the field, only *Delia antiqua* and *Panonychus ulmi* have developed some resistance.

Pest resistance has been documented to 20 of the 69 active ingredients used since 1945. Two pest species in the fields, two pest species in greenhouses and three pest species indoors were found to have developed insecticide or acaricide resistance of some stage.

Index words: pesticide resistance, cross-resistance, DDT, lindane, cyclodienes, organophosphates, pyrethrin, pyrethroids, *Musca domestica, Blattella germanica, Tribolium confusum, Myzus persicae, Tetranychus urticae, Delia antiqua, Panonychus ulmi.*

INTRODUCTION

The introduction of new organic insecticides to the Finnish market followed the international trend that started in the 1940's. The chlorinated hydrocarbons: DDT and HCH were introduced to the market in 1945. Organic pyrophosphates and parathion followed within two years. Demeton, the first systemic organophosphate, was marketed in 1951, and in 1955, organic cyclodienes and a whole series of different organophosphorus compounds became available. Since their introduction, these synthetic insecticides prevailed the market. The use of older, inorganic insecticides were discontinued by 1964, but the traditional

botanic insecticides still remained. The use of carbamates as insecticides and acaricides has been more recent and selective.

The amount of active ingredients used for animal pest control between the years of 1953 and 1967 totalled 1412 tons. The annual amount averaged 94 tons (MARKKULA and TIITTANEN 1969). The amount used in 1968—82 totalled 1936 tons, a yearly average of 129 tons (MARKKULA 1967—75, TIITTANEN and BLOMQVIST 1976—82). The amounts of rodenticides, molluscicides and nematicides are included but are less than 0,5 % of these values.

Since 1945 69 different insecticidal and acaricidal active ingredients have been used. In 1984, two of the compounds, parathion and sulfotep, used in the 1940's were still being marketed. The compounds introduced between 1945 and 1984 had been on the market an average of 16 years. During 1962, the highest number of commercial products were in use (MARKKULA 1967—75). There were 105 products available for agricultural pests, and 110 for indoor pests (KÖPPÄ 1963). This is compared to the 52 products available for agricultural pests and 49 for indoor pests in 1982 (TIITTANEN and BLOMQVIST 1983).

Over 40 % of the amount of active ingredients in insecticides and acaricides were used indoors at the end of the 1960's (MARKKULA 1967—75). These were specifically used for controlling houseflies, cockroaches, storage beetles, and moths. About ten insect and mite species indoors were frequently controlled by chemicals. By 1982, the relative amount of indoor insecticides had decreased to 5 %. This decrease was due to better sanitation. Additionally the use of pyrethrin and pyrethroid preparations had by that time become popular indoors. These preparations had very low doses of active ingredients.

Especially between the periods of 1972 thru 1974, and 1978 thru 1980 the amount of active ingredients used for controlling pests on plants increased (MARKKULA 1967—75, TIITTANEN and BLOMQVIST 1976—80). About 40 major plant pests were applicated by chemicals every year. The use of chemicals was most intensive in greenhouses. For example cucumber growers used an average of nine applications annually (MARKKULA et al. 1972). The relevant pests in greenhouses were mites and aphids (MARKKULA 1969).

Pests that are exposed to extensive (through several life stages) residual or environmentally durable pesticides, can be expected to develop a faster rate of resistance (e.g. GEORGHIOU and TAYLOR 1967). The selection is intensified in habitats where applications are prescribed at a low threshold of pest density. In addition, KEIDING (1977) regards the living of the pest in semi-isolated populations as another essential element aggravating the development of resistance. On the basis, the situation of pest control in greenhouses and indoors can easily be expected to favor development of resistance.

This review will discuss the verified and potential changes in control practices caused by the resistance found in pests since 1945. The word resistance is used as defined by FAO (ANON. 1967). The primary documents are collected from the Department of Pest Investigation in the Agricultural Research Centre, Jokioinen. This material, together with the published records of resistance, is organized according to the chemical groupings: DDT, HCH and lindane, cyclodienes, organophosphates, carbamates, pyrethrin and pyrethroids (Appendix). In addition to the conventional insecticides, the potential resistance against a commercial biological agent and the effort to induce resistance in a biological control agent are shortly mentioned.

1. DDT

Resistance in the housefly

DDT was introduced to the market in the form of dusts, sprays, strips and smoke preparations. For better control simultaneous application of DDT into the incubation substrates of fly larvae and around the areas of adult flies was recommended.

The speculations of resistance in the housefly *Musca domestica* L. were started in 1947 (KANERVO 1947). A special product was introduced in 1949 to eliminate the increasing resistance problems of DDT. This product was a paper strip, impregnated with a mixture of thanite (isobornyl thiocyanoacetate) and DDT. It was supposed to withstand the development of resistance (ANON. 1949). However, in 1950 after the failures in the control practice, the risk of resistance to DDT was acknowledged (EKHOLM 1949, KANERVO 1951, MARKKULA 1952). It was then considered to discontinue using DDT by the end of the 1950's.

The first resistance studys done in Finland in 1955 showed that ten per cent of the houseflies originating from the problem areas were unsusceptible to normal doses of DDT (ANON. 1946—72). In the tests done by KEIDING (1980) a Finnish strain, originating from a pig farm showed a high resistance to DDT. No other pests were known to have acquired resistance to DDT in Finland.

2. HCH and lindane

Resistance in the housefly

In the beginning of the 1950's, the use of HCH products gained substantial popularity indoors (MARKKULA 1954). The smoke preparations were instantly adopted to the control of adult houseflies and the dust formulates for the control of larvae. In addition, lindane was established as a storage insecticide, sold later in sprays and aerosols.

The use of HCH in housefly control had just been extended, when suggestions of resistance to HCH in many local housefly populations were published (MARKKULA 1954—57, 1955, TALVITIE 1954 a). Simultaneously a sales increase of lindane and HCH occurred (MARKKULA 1954—57, 1955), because in problem areas it was recommended to use higher doses of active ingredients (EKHOLM 1952).

In 1954 the public recommendations about lindane in housefly control were reconsidered (TALVITIE 1954 b, TERVO 1954). The resistance of houseflies to lindane was never verified in the laboratory. However, by 1957 the sale of these smoke preparations had dropped to only 8 % of the amount sold in 1953. According to MARKKULA and ROIVAINEN (1959), this resulted from the resistance in houseflies to lindane. Meanwhile, the first organophosphorus compounds and pyrethrin achieved a significant role in fly control.

Variable resistance in root maggots

For pest control on plants, HCH and lindane were sold as alternatives to DDT, and in a minor extent, were also mixed with DDT. The amount of lindane used in the field was highest in 1966, when strewing powders had become the major formulates (MARKKULA 1967—75).

The efficiency of lindane in powder form was observed annually since 1947. These observations were made in field experiments on onions. A distinct decrease in the effect of lindane against root maggots *Delia antiqua* Mg. was detected in 1953. In 1957 practically no control with lindane was achieved in these same experiments, even though each year the dose of lindane was increased (KANERVO and TIITTANEN 1962).

After lindane had been used for 25 years in

the control of root maggots, cabbage root flies *Delia radicum* (L.), and turnip root flies *Delia floralis* (Fall.), the poor effects of this compound was confronted by the cabbage growers. The inefficiency of a granulate containing 0,46 % lindane was confirmed in field experiments, in which the turnip root fly dominated (VARIS and DALMAN 1980). However, in laboratory studies on resistance only a 2—3 -fold increase in differences were found in the LC50 of larvae between the tolerant and the suscebtible strains of the turnip root fly (VARIS and DALMAN 1980). For a different response to lindane in the field and laboratory, they suggest the need of a latent period before the higher levels of specific resistance are developed.

The effects of lindane on cabbage flies was previously tested by Tiittanen in 1961—66, but no sign of resistance was detected (ANON. 1946—72). After new compounds and comparable formulates of organophosphates with systemic or long lasting effects penetrated the market, lindane was gradually discontinued in controlling root maggots.

3. Cyclodienes

Cyclodienes received a minor and more random importance than lindane or DDT (MARKKULA 1967—75). Chlordan was on the market already in 1945 as a mixture with DDT, the aldrin, dieldrin and endrine became available in 1958—59. Aldrin and endrine were used in the field, dieldrin and chlordan were mainly used indoors. All cyclodienes except endrin were banned by 1970.

The cross-resistance to cyclodienes in the housefly strains that were resistant to DDT and lindane was self-evident (TALVITIE 1954 b), but was actually not verified. The resistance to dieldrin lacquer in locally distributed cockroach *Blattella germanica* (L.) colonies were detected in 1965 (ANON. 1946—72, ANON. 1968).

The resistance of onion root maggots to lindane did not instantly lead to a resistance to the cyclodienes, aldrin and dieldrin (KANERVO and TIITTANEN 1962). These experiments with aldrin and dieldrin were continued by Kanervo and Tiittanen for an additional five years, but no resistance in root maggots developed (ANON. 1946—72).

4. Organophosphates

Widely resistant housefly

Fly gauzes containing parathion were adapted to housefly control in cowsheds in 1955 after lindane was no longer effective (MARKKULA and ROIVAINEN 1959). In 1959 houseflies were reported to be avoiding the fly gauzes (TINNILÄ 1960), a phenomenon, which has been explained as a behavioral resistance (KILPATRIC and SCHOOF 1958). As expected, (TINNILÄ 1960) the sales of the fly gauzes dropped abrubtly (MARKKULA and RUUTTUNEN 1961).

The next major group of compounds introduced to fly control were trichlorphon, dichlorvos, fenchlorphos and dimethoate, these were baits, fenthion, dimethoate and bromophos were sprays and dimethoate was a new fly gauze. In the beginning of the 1970's an increasing number of fly populations had developed a resistance to dichlorvos (Alpo Aapola, oral comm.) and also to bromophos (RAUTAPÄÄ 1973). This resistance was verified by FEAKINS and TIPTON (1971). Their results showed a resistance ratio of x12,2 at LD50 to vapour exposure of dichlorvos between the tolerant housefly strain from Jalasjärvi in the West of Finland and a susceptible control strain.

The continued tests with the Jalasjärvi strain confirmed the resistance of the flies to a broad spectrum of organophosphorus insecticides. The following resistance ratios at LD50 in the topical application of the F3 generation were: dichlorvos x9,6 (vapour application x13,3), dimethoate x8,0, tetrachlorvinphos x3,1 and crotoxyphos x13,7. After subsequent gener-

ations had been exposed to dichlorvos vapour the ratios in the F6 generation were: dichlorvos x4,6 (vapour application x18), dimethoate x8,0, tetrachlorvinphos x1,6, crotoxyphos x40, bromophos x19 and trichlorphon x29 (FEAKINS and TIPTON 1971). GEROLT (1974) used the same fly strain in his studies on the mechanism of dichlorvos resistance.

Rautapää also detected a resistance to dimethoate in two fly strains originating from pig farms in Huittinen and Kytäjä (ANON. 1979). One of these strains showed a moderate dimethoate-resistance with the ratio x7 at LD50, and the other showed a low resistance with the ratio x4 at LD50 (KEIDING 1980).

Most of the observations and suggestions of the resistance in houseflies to organophosphates were documented from the regions where DDT resistance had previously prevailed (Jorma Rautapää, oral comm.). However, it was possible to control the resistance of houseflies to organophosphates. This was done by altering the organophosphate compounds and periodically shifting to pyrethrin.

Extended resistance of the green peach aphid

In the control of aphids in greenhouses, the organophosphates surpassed nicotine and hydrogen cyanide in the 1950's. The first compounds to be intensively used were parathion and demeton sprays, and vapour formulates containing sulfotep and diazinon.

In 1967 80 % of the greenhouse growers using parathion for aphid control rated its effects poor. 60 % had similar opinions about sulfotep, and 50 % thought the same about diazinon (MARKKULA 1968). These results were verified in the laboratory by Markkula and Tiittanen. They tested 24 strains of green peach aphids *Myzus persicae* (Sulz.) from greenhouses where the problems were reported (ANON. 1969). These aphids were exposed to residual insecticide on chrysanthemum leaves that were dipped into a recommended concentration of insecticide solution. In solutions of 0,0175 % parathion, a decreased effect was detected in 21 of the 24 aphid strains. In solutions of 0,012 % mevinphos the decreased effect was in 20 of the 24 strains, and in solutions of 0,1 % bromophos the decreased effect was in 19 of the 24 strains. One of the strains that was unsusceptible to these insecticides also showed slight tolerance to dimethoate. Except for one strain, all strains were susceptible to 0,1 % dimethoate (40 % active ingredient) and 0,25 % nicotine (40 % active ingredient) (ANON. 1946—72). No tests were conducted with sulfotep or diazinon.

Two of the 24 tested strains together with four new strains were then studied by SELANDER et. al. (1972). He concentrated on defining the strength and heterogenity of aphids resistance to parathion, malathion, dimethoate, lindane, pirimicarb and nicotine. Even though these strains differed in their susceptibility to organophosphates (SELANDER 1970), all of them were found resistant to the first four insecticides, but were susceptible to nicotine and to pirimicarb. The most resistant strain to parathion showed heterogeneity in its reaction to pirimicarb. Melon aphids, *Aphis gossypii* Glov. and solanum aphids, *Aulacorthum solani* (Kalt.) were found to be 13 to 34 times more susceptible to parathion than the least resistant strain of green peach aphids (SELANDER et. al. 1972).

Markkula and Tiittanen found the organophosphate-resistant strains of green peach aphid to be highly susceptible to aldicarb (ANON. 1972). In addition, nicotine and pirimicarb could be used for aphid control in flower cultivations. For greenhouse vegetables the biological control agent, predatory gall midge *Aphidoletes aphidimyza* (Rond.) was introduced in 1978. This predator partially replaced the short lasting organophosphates, like mevinphos.

Immediate resistance in the two-spotted spider mite

Between the years 1946 and 1957 demeton and parathion were succesfully used in controlling the two spotted spider mite, *Tetranychus urticae* Koch, in greenhouses (ANON. 1957). By 1959, Tiittanen concluded that these compounds were no longer effective (ANON. 1959). The resistance studies were performed in 1960, when resistance to parathion was confirmed and a decreasing effect of demeton-S-methyl was found (ANON. 1960). In the 1960's, mites were found to be widely unsusceptible to organophosphates (ANON. 1961, SILVO 1960), and in 1970, the effects of all organophosphates in mite control were declared unsatisfactory in greenhouses (MARKKULA and TIITTANEN 1970). Some of the two-spotted spider mite colonies on small fruits were also found unsuscebtible to organophosphates (Tuomo Tuovinen, oral comm.).

The studies on organophosphates were later completed by HURKOVA and TIITTANEN (1982). They found that the mites were more resistant to the selection compounds. The resistance ratio of parathion was x63, of malathion x142, of mevinphos x33, of azinphos-ethyl and of diazinon x15 at LC50. For sulfotep, demeton-S-methyl, dimethoate and bromophos, the resistance ratios were never defined, but the resistance has appeared clearly in practice and has been included in the FAO resistance report (GEORGHIOU 1981). High resistance ratios were also found with some compounds never sold in Finland: amidithion x265, thiometon x70 and methidathion x63 at LC50 (HURKOVA and TIITTANEN 1982).

As the resistance in mites to organophosphates became clear, carbamates and the acaricides, which were earlier used parallel with organophosphates, became more dominant. The predatory mite *Phytoseiulus persimilis* A.—H. also started being used instead of organophosphates in mite control on greenhouse vegetables.

Resistance of the European red mite

Organophosphates were used with variable success as summer sprays against European red mites *Panonychus ulmi* (Koch) (KANERVO 1960). The effects depended on the timing of the application, but gradually the decreased effects of these conventionally used organophosphates, parathion and dimethoate were noticed and considered resistance (Tuomo Tuovinen, oral. comm.). The results have become even more negative because natural enemies, susceptible to organophosphates, have died. No documents of the mite resistance to acaricides have been given.

5. Carbamates

Resistance of the two-spotted spider mite to aldicarb

Carbamates, particularly aldicarb, have been used in flower cultivations mainly as systemic insecticides applied to the plant roots. Aldicarb granulates had only been in experimental use for two years, when in 1970, mites were found to have become unsusceptible to aldicarb. This resistance was verified in the laboratory by MARKKULA and TIITTANEN (1970). They found that the resistant mite strain had a mortality rate of only 59 %, when transferred to plants treated with aldicarb (10 % active ingredient, 7 g/m^2 soil). The strain was still susceptible to dicofol (MARKKULA and TIITTANEN 1970).

No cross-resistance to aldicarb was detected in the organophosphate-resistant mite strains (HURKOVA and TIITTANEN 1982). The use of carbamates has remained limited in greenhouses and no signs of resistance in other pests have been documented.

Suspected resistance in the cockroach to propoxur

The long residual effects of carbamates have been exploited on various surfaces indoors. It has been increasingly reported by professional

pest control operators that propoxur is no longer an effective method for cockroach control (Pehr Ekbom, Kaarlo Satimus, oral comm.). No resistance tests have been done, and propoxur today, is still used indoors.

6. Pyrethrin

In 1951 pyrethrin was introduced to market as processed insecticide. It was specially produced in aerosol form to control indoor house flies. Pyrethrin products were to replace the former lindane products. Later, pyrethrin was widely used to control pests on plants, thus replacing the ineffective organophosphates.

In 1967 the resistance to pyrethrin was documented in a cockroach strain (ANON. 1967), and, in 1978, Rautapää found that the dimethoate resistant housefly strain from Huittinen was also resistant to pyrethrin (ANON. 1979). The resistance was moderate with the ratio x5 at LD50 (KEIDING 1980). The same resistance was found in another fly strain in 1982 (Helena Granlund, oral comm.).

7. Pyrethroids

Pyrethroid allethrin was introduced in 1960 followed by tetramethrin in 1975. They only stayed on the market for a few years, while cypermethrin, deltamethrin and permethrin were expanding.

In addition to the pyrethrin resistance, the Huittinen strain of houseflies showed strong resistance to the pyrethroids, fenvalerat and permetrin (ANON. 1979). At LD95 the resistance ratio to permethrin was x82 and it was at LD50 x34 (KEIDING 1980). A slight resistance to fenvalerat appeared in a strain from Kytäjä (ANON. 1979).

8. Miscellaneous

Methyl bromide and phosphine

Methyl bromide and phosphine have been used restrictively by professional pest control operators. An international survey on storage pests showed that only a low resistance to these insecticides was found in a single strain of *Tribolium confusum* (CHAM and DYTE 1976). This case, however, has very little, or no practical importance.

Bacillus thuringiensis

The commercial preparation of *Bacillus thuringiensis* exotoxin for fly control was developed by Gunnel Carlberg (University of Helsinki, Department of Microbiology) and it was registered by Farmos Group Ld. in Finland in 1981. The resistance tests were organized with *Drosphila melanogaster* Mg. A 10-fold increase in resistance was developed in 30 generations of fruit flies reared in a medium containing 0,5 to 1,0 % of the preparation (CARLBERG and LINDSTRÖM 1981). No significant resistance was achieved with continued exposure, and the low rate of resistance that was found, proved to be fairly unstable (Gunnel Carlberg, oral comm.).

Phytoseiulus persimilis

MÄNTTÄRI (1980) tried to develop a pyrethroid resistant strain of the predatory mite *Phytoseiulus persimilis*. The mites were selected for resistance in 50 successive generations exposed to gradually increasing concentrations of bioresmethrin. The highest concentration was 20-fold. Some mite strains were exposed to gamma-radiation in order to induce genetic variation. After 14 generations, the resistance ratio was as low as x1,7 and the radiation did not give any results. Resistance could not be developed, and in the final test the normal concentration of bioresmethrin, which is the same as the starting concentration in selection experiment, was lethal to the adults of the selected strain (MÄNTTÄRI 1980).

EFFECT OF RESISTANCE ON PEST CONTROL

Widespread resistance was detected in the frequently controlled indoor pests, the housefly and the cockroach, and in the major greenhouse pests, the green peach aphid and the two-spotted spider mite. Among the field pests, only the root maggots and the European fruit mite developed resistance. Of the 69 active ingredients used in Finland since 1945, pest resistance developed in 20, three chlorinated hydrocarbons, eleven organophosphates, aldicarb, pirmicarb, permethrin and pyrethrin and, in addition, to phosphine and methyl bromide (Appendix).

No economic losses or insuperable control problems have been documented as directly or indirectly associated to the development of resistance. Normally, new insecticides and acaricides were started being used before the resistance to former compounds became extended. This happened because of the better effects, safer standards, and shorter residual age of the new compounds. Changes from chlorinated hydrocarbons to organophosphates, acaricidal compounds and pyrethroids, and the introduction of new forms of application have been necessary. Cross-resistance has appeared, for instance between DDT and other chlorinated hydrocarbons and between different organophosphates. However, effective alternatives with different modes of action have been available. Many new compounds, especially those that are restricted in use, have been more expensive than their precedants.

A lack of compounds with short residual effect was faced by the growers of greenhouse vegetables, after the resistance of green peach aphids to organophosphates developed. This essentially helped the biological control agent, *Aphidoletes aphidimyza* (Rond.), to be accepted as an alternative to chemicals. Biological control has been distributed to new areas, enhanced by the ideas of biological cultivation.

APPENDIX

The insecticides and acaricides used in Finland since 1945 and the occurrence of resistance against them. If not verified in laboratory marked with ?.

Compounds	Years used	Resistant pest species and the year resistance stated
Chlorinated hydrocarbons:		
BHC, HCH, Lindane	1945—84	1953 *Delia antiqua* 1954 *Musca domestica* 1972 *Myzus persicae*
DDT	1945—75	1951 *Musca domestica*
Hexachloroetane	1953—	
Chlordane	1955—62	1954 *Musca domestica* ?
Dieldrin	1958—70	1954 *Musca domestica* ? 1965 *Blattella germanica*
Aldrin	1959—66	1954 *Musca domestica* ?
Methoxychlor	1961—	
Endosulfan	1962—	
Perthane	1962—	
Strobane	1968—69	
Dicofol	1973—	
Chlorobenzilate	1973—	
Organophosphates:		
Sulfotep	1946—	1960 *Tetranychus urticae*
TEPP, HETP	1946—66	
Parathion, parathion-methyl	1947—	1959 *Musca domestica* 1960 *Tetranychus urticae* 1960's *Panonychus ulmi* ? 1969 *Myzus persicae*
Demeton, demeton-S-methyl, oxydemeton-methyl	1951—	1960 *Tetranychus urticae* 1969 *Myzus persicae*
Malathion	1955—	1961 *Tetranychus urticae* 1960's *Panonychus ulmi* ? 1972 *Myzus persicae*
Diazinon	1959—	1960 *Tetranychus urticae* 1969 *Myzus persicae*
Trichlorfon	1959—	1971 *Musca domestica*
Dichlorvos	1961—	1971 *Musca domestica*
Fenthion	1961—77	

Fenchlorphos	1962—	
Phorate	1962—65	
Mevinphos	1962—	1969 *Myzus persicae*
		1982 *Tetranychus urticae*
Naled	1963—	
Dimethoate	1964—	1965 *Tetranychus urticae*
		1960's *Panonychus ulmi ?*
		1971 *Musca domestica*
		1972 *Myzus persicae*
Bromophos	1965—	1965 *Tetranychus urticae*
		1969 *Myzus persicae*
		1971 *Musca domestica*
Formothion	1965—71	
Trichloronate	1967—74	
Fenitrothion	1971—	
Phoxim	1971—	
Iodofenphos	1974—	
Azinphos-methyl	1978—	1982 *Tetranychus urticae*
		1980's *Panonychus ulmi ?*
Chlorpyriphos	1979—	
Isofenphos	1980—	
Carbamates:		
Prothiocarb	1945—52	
Dimetilan	1961—69	
Propoxur	1969—	1980's *Blattella germanica ?*
Aldicarb	1970—	1970 *Tetranychus urticae*
Formetanate	1974—76	
Pirimicarb	1976—	1972 *Myzus persicae*
Butoxycarboxim	1981—	
Pyrethroids:		
Allethrin	1960—67	
Tetramethrin	1975—78	
Deltamethrin	1982—	
Cypermethrin	1983—	
Permethrin	1984—	1979 *Musca domestica*
Inorganics:		
Calcium arsenate	1890—1964	
Lead arsenate	1890—1959	
Natrium cyanide	1946—53	
Zinc arsenate	1954—55	
Natrium silicofluorid	1955—61	

Botanic insecticides:

Nicotine	1890—	
Rotenone	1920—	
Pyrethrin	1951—	1967 *Blattella germanica*
		1978 *Musca domestica*

Acaricides:

Tetradifon	1945—52
Aramite	1964—72
Dienochlor, pentac	1973—
Chinomethionate	1973—
Chlordimeform	1974—76
Dinobuton	1978—

Miscellaneous:

Naphtalene	1890—	
Mineral + tar oils	1890—	
DNOC	1946—68	
P-dichlorbentsene	1948—	
Methanesulfonyl fluoride	1958—77	
Paraffin	1978—	
Phosphine		1974 *Triboliom confusum*
Methyl bromide		1974 *Triboliom confusum*

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SELOSTUS

Katsaus hyönteisten ja punkkien torjunta-aineresistenssiin

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Maatalouden tutkimuskeskus

Kemiallisen torjunnan nopea kehitys alkoi DDT:n käyttöön tulosta 1940-luvun puolivälissä. Ensimmäiset käytännön havainnot siitä, että tuholaiset olivat kehittyneet resistenteiksi uudenaikaisia torjunta-aineita vastaan, tehtiin Suomessa 1950-luvun alussa viitisen vuotta uusien aineiden käyttöön tulon jälkeen.

Resistenssitapaukset

DDT:stä ja lindaanista jouduttiin luopumaan huonekärpäsen torjunnassa jo 1950-luvun puolivälissä valmisteiden tehottomuuden tähden. Resistenssi oli laaja-alaista ja todellista, vaikkakaan sitä ei tarkistettu laboratoriotutkimuksin.

Myöhemmin 1970-luvulla huonekärpäsessä todettiin kehittyneen resistenssiä useita orgaanisia fosforiyhdisteitä, ja 1970-luvun lopussa myös pyretriiniä ja pyretroideja vastaan. Resistenssin kehittymistä *Bacillus thuringiensis* -bakteerin tuottamaa eksotoksiinia vastaan pidetään alustavien kokeiden perusteella epätodennäköisenä.

Sisätilojen muiden tuholaisten resistenssi on ollut varsin lievää. Russakan resistenssi dieldriiniä sisältävää torjuntalakkaa vastaan ilmoitettiin 1968 ja saman lajin kestävyydestä propoksuria vastaan on tehty useita havaintoja käytännön torjuntatilanteissa.

Sipulikärpäsen todettiin kehittyneen resistentiksi lindaania vastaan 1950-luvun lopussa, kun torjuntakäsittelyt olivat kohdistuneet kärpästoukkiin toistuvasti muutamina vuosina. Kaalikärpästen resistenssiä koskeneet epäilyt 1970-luvun puolivälissä vahvistuivat myöhemmin kenttäkokeiden perusteella, mutta laboratoriossa resistenssi osoittautui kovin heikoksi.

Persikkakirvan resistenssi lindaania ja useita orgaanisia fosforiyhdisteitä vastaan osoitettiin varmasti 1960-luvun lopussa. Myös vihannespunkin kestävyys sekä aldikarbia että orgaanisia fosforiyhdisteitä vastaan todettiin 1960-luvun lopulla. Hedelmäpuupunkin kestävyyttä orgaanisia fosforiyhdisteitä vastaan on ilmoitettu käytännössä usein havaitun, mutta sitä ei laboratoriossa ole varmistettu. Punkkien resistenssiä akarisidejä vastaan ei ole ilmennyt.

Resistenssin yleisyys

Ainoastaan neljän pelto- ja puutarhakasveissa esiintyvän tuholaislajin todettiin kehittyneen resistenteiksi. Kun säännöllisesti vuosittain torjuttavia kasveissa esiintyviä tuholaislajeja on nelisenkymmentä, on siis joka kymmenennessä havaittu resistenssiä. Sisätilojen tuholaisten resistenssiä torjunta-aineita vastaan on havaittu kolmessa lajissa, kun yleisimmin torjuttuja lajeja on noin kymmenen.

Vuodesta 1945 lähtien maassamme on yleisesti käytetty 69 erilaista tehoainetta hyönteisten ja punkkien torjuntaan. 1940-luvulla käyttöön otetuista tehoaineista kaksi: parationi ja sulfoteppi olivat käytössä vielä vuonna 1984. Vuoteen 1984 mennessä käytössä olleiden tehoaineiden keskimääräinen käyttöaika oli noin 16 vuotta.

Resistenssiä on todettu kehittyneen 20 tehoainetta vastaan. "Resistenssiaineista" enimmät, kaikkiaan yksitoista kuuluvat organofosfaatteihin: parationi, demetoni, diatsinoni, sulfoteppi, malationi, dimetoaatti, bromofossi, mevinfossi, diklorvossi, triklorfoni ja atsinfossi-metyyli. Kloorattuja hiilivetyjä on kolme: DDT, lindaani ja dieldriini. Muut kuusi ovat aldikarbi, pirimikarbi, pyretriini, permetriini, metyylibromidi ja fosfiini.

Resistenssin merkitys

Merkittäviä taloudellisia tappioita ei ole ilmennyt suoranaisesti tai välillisesti torjunta-aineresistenssin kehittymisestä. Tappiot ovat rajoittuneet yhteen tai muutamaan epäonnistuneeseen torjuntakertaan, jonka jälkeen viljelijä on ryhtynyt käyttämään jotain muuta torjunta-ainetta. Yleensä aina on ollut saatavilla useita erilaisia tojunta-aineita korvaamaan tehonsa menettäneitä aineita. Tosin usein uudet, "korvaavat aineet", esimerkiksi pyretriini, pyretroidit ja akarisidit ovat olleet kalliimpia kuin aikaisemmat laajalti käytetyt tehoaineet, esimerkiksi DDT, lindaani ja parationi. Uudet tehoaineet ja kauppavalmisteet ovat useimmiten tulleet käyttöön muista syistä kuin resistenssin tähden. Ne ovat olleet aiempia tehokkaampia, nopeammin hajoavia taikka turvallisempia käyttäjille, kuluttajille ja ympäristölle.

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Seria ANIMALIA NOCENTIA N. 121 — Sarja TUHOELÄIMET n:o 121

Research note

THE EFFECTS OF CERTAIN PLANT EXTRACTS ON THE FEEDING AND MORTALITY OF *PHYLLOTRETA UNDULATA (COLEOPTERA: CHRYSOMELIDAE)*

IRMA LÖFSTRÖM

LÖFSTRÖM, I. 1985. **The effects of certain plant extracts on the feeding and mortality of *Phyllotreta undulata (Coleoptera: Chrysomelidae)*.** Ann. Agric. Fenn. 24: 175—178. (Agric. Res. Centre, Inst. Pest Inv., SF-31600 Jokioinen, Finland.)

The effects of nine aqueous plant extracts on the feeding and mortality of *Phyllotreta undulata* was studied under laboratory conditions. The extracts were made from the following plants: *Lycopersicon esculentum, Urtica dioica, Equisetum arvense, Petroselinum crispum* and *Sambucus racemosa.* Concentrate from the berries of *S. racemosa* was also studied. Seedlings of *Raphanus sativus* were treated with the different plant extracts and water, which was used as a control. The beetles were allowed to feed on the treated leaves for four days.

The extracts had no effect on the mortality of the flea beetle. However, the extract from mature, dried and ground berries of *S. racemosa* significantly decreased the amount of plant damage caused by the beetles. The results indicate that *S. racemosa* extracts made from dried berries, contains some substances which inhibit the flea beetles from feeding on the treated radish leaves.

Index words: aqueous plant extracts, *Phyllotreta undulata,* feeding, mortality.

INTRODUCTION

A number of studies have shown that plant extracts kill (PANDEY and VERMA 1982, DREYER 1984) or inhibit the feeding or oviposition of pests (ROBERT 1976, ABIVARDI and BENZ 1984, KAREL and HONGO 1984). This study investigated the effects of aqueous plant extracts from five different species on the mortality of *Phyllotreta undulata* (Kutsch.), and on the amount of damage caused to radish leaves in laboratory conditions.

MATERIAL AND METHODS

Plant extracts were mixed with cold tap water from the following plants and parts thereof: tomato (*Lycopersicon esculentum*) — fresh shoots (20 %), nettle (*Urtica dioica*) — fresh (20 %), and dried (2,5 %) young shoots, common horsetail (*Equisetum arvense*) — fresh shoots (2,5 %), parsley (*Petroselinum crispum*) — dried shoots (2,5 %) and red elder (*Sambucus racemosa*) — dried leaves (2,5 %) and dried mature berries (2,5 %). Extracts from dried mature berries of the red elder sealed in plastic for a year (2,5 % and 1,25 %) and concentrate from the fresh mature berries (100 % concentrate and concentrate + water 1:1) were also tested.

Tomatoes and parsley were grown in greenhouses, while the other plants were gathered from the surroundings of the Agricultural Research Centre, Jokioinen, (Grid 27°E 674:30, latitude 60°48'N). The extracts were processed through a 0,42 mm pore size sieve to eliminate the coarse plant material. Water was used as a control.

Adult flea beetles were collected from the Research Centre fields in the summers of 1983 and 1984 around 1—2 weeks before the experiments began. Two week old radish (*Raphanus sativus* var. non plus ultra) seedlings, bearing cotyledons and foliage leaves, were treated with the plant extracts. The seedlings were submerged in the extracts upside down, the leaves and stems being thoroughly soaked. The treated seedlings were placed in colourless 5-litre glass jars (4 seedlings/jar), and 25 flea beetles were dropped into each jar. Then the jars were sealed with gauze. The experiments were repeated 4 times. The temperature in the laboratory was 23 ± 2 °C and relative humidity was 70 ± 10 %.

The live flea beetles were counted 1 day and 4 days after the beginning of the experiment. After 4 days the experiment was stopped, the flea beetles were removed from the jars and the damage caused by them was measured. The holes from the radish leaves were traced to a transparent membrane, and then counted.

RESULTS AND DISCUSSION

None of the extracts investigated had any effect on the mortality of the flea beetles. Extracts made from the species *Urtica dioica, Equisetum arvense, Lycopersicon esculentum* and *Petroselinum crispum* and the extract from the leaves of the *Sambucus racemosa* species had no effect on the amount of damage to the leaves (Table 1).

The 2,5 % extract made from mature, dried and ground berries of the *S. racemosa* significantly reduced the damage caused by the beetles ($F=12,6$, $n=4, 16$, $\bar{x}=0,030$, control $\bar{x}=14,32$). A similar extract, which was made from dried berries preserved in a plastic bag for 1 year, gave comparable results (Table 1). The *S. racemosa* extract, diluted to half its strength, also reduced the damage caused by the flea beetles.

The aqueous concentrate from fresh mature berries dried some of the radish seedlings. Therefore, the low incidence of damage on leaves treated with aqueous concentrate from berries is likely to be due to the fact that leaves that had suffered from the treatment were no longer suitable for flea beetles to feed on. When the concentrate was mixed with water in a 1:1 ratio, the leaves of the radish suffered less and the amount of damage increased. The

Table 1. Damage caused by flea beetles (number of holes/flea beetle, average) on radish leaves treated in different ways.

Treatment (extract or concentrate)			Number of holes		F-	Signi-
Species	Plant part	Conc., %	$\bar{x}$	Control $\bar{x}$	value	fic.
Equisetum arvense	fresh shoots	20	27,41	28,22	1,26	NS
Lycopersicon esculentum	fresh shoots	20	21,89	28,22	1,26	NS
Petroselinum crispum	dried shoots	2,5	21,31	24,15	2,13	NS
Urtica dioica	fresh shoots	20	19,69	28,22	1,26	NS
Urtica dioica	dried shoots	2,5	19,72	24,15	2,13	NS
Sambucus racemosa	dried leaves	2,5	10,80	24,15	2,13	NS
Sambucus racemosa	dried berries	2,5	0,03	14,32	12,60	*
Sambucus racemosa	dried berries o	2,5	9,34	40,39	24,26	*
Sambucus racemosa	dried berries o	1,25	10,70	19,78	4,81	NS
Sambucus racemosa	berries, conc.	100	1,74	19,78	4,81	*
Sambucus racemosa	berries, conc. + water	50	6,63	19,78	4,81	NS

o = one year old
NS = non-significant
* $P<0,05$

relative amount of damage sustained by radish leaves treated in different ways is shown in Fig. 1.

On the basis of these experiments it can be concluded that the berries of the *Sambucus racemosa* species contain one or more compounds which, when dissolved in water and applied to radish leaves, prevents the feeding of the flea beetles and thus reduce the damage caused to the plants.

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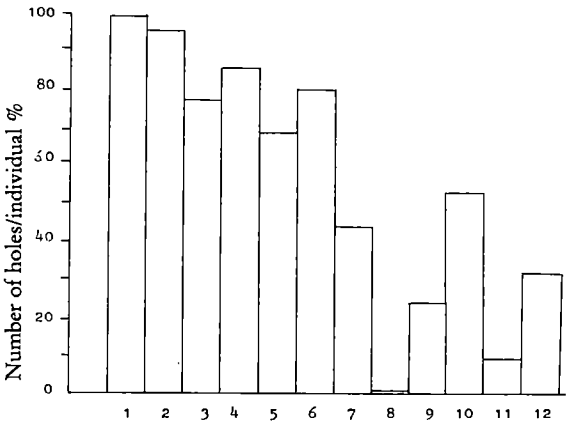

1 = Water (control), 2 = *Equisetum arvense*, fresh shoots (20 %), 3 = *Lycopersicon esculentum*, fresh shoots (20 %), 4 = *Petroselinum crispum*, dried shoots (2,5 %), 5 = *Urtica dioica*, fresh shoots (20 %), 6 = *U. dioica*, dried shoots (2,5 %), 7 = *Sambucus racemosa*, dried leaves (2,5 %), 8 = *S. racemosa*, dried berries (2,5 %), 9 = *S. racemosa*, one year old dried berries (2,5 %), 10 = *S. racemosa*, one year old dried berries (1,25 %), 11 = *S. racemosa*, concentrate (100 %), 12 = *S. racemosa*, concentrate + water (50 %)

Fig. 1. The feeding (number of holes/individual) of *Phyllotreta undulata* on radish leaves treated with water (control), plant extracts or concentrate.

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SELOSTUS

Kasviuutteiden vaikutus aaltojuovakirpan (*Phyllotreta undulata*) syöntiin ja kuolleisuuteen

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Maatalouden tutkimuskeskus

Tuholaisten torjumista pehmeän tekniikan menetelmin on ryhdytty tutkimaan aiempaa enemmän. Kasveista on mahdollista löytää aineita, jotka ovat myrkyllisiä tuholaisille, karkottavat ne viljelykasveilta tai estävät niiden lisääntymistä.

Tässä tutkimuksessa selviteltiin tomaatista, nokkosesta, peltokortteesta, persiljasta ja terttuseljasta valmistettujen vesiuutteiden sekä terttuseljamehun vaikutusta aaltojuovakirpan (*Phyllotreta undulata*) kuolleisuuteen ja kykyyn vioittaa retiisin lehtiä laboratoriossa. Vertailukohteena käytettiin pelkkää vettä. Retiisin lehdet kasteltiin eri uutteilla ja vedellä, ja kirpat saivat syödä niitä 4 vrk:n ajan.

Mikään tutkituista uutteista ei vaikuttanut kirppojen kuolleisuuteen. Kuitenkin terttuseljan kuivatuista, jauhetuista marjoista valmistettu uute vähensi merkitsevästi kirppojen vioitusta retiisin lehdissä. On ilmeistä, että terttuseljan marjat sisältävät yhden tai useita yhdisteitä, jotka ehkäisevät kirppojen syöntiä. Jatkotutkimukset mm. ehkäisevän vaikutuksen pysyvyyden selvittämiseksi ovat tarpeen.

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Seria HORTICULTURA N. 52 — Sarja PUUTARHAVILJELY n:o 52

Research note

A FINNISH STRAWBERRY VARIETY 'HIKU'

HEIMO HIIRSALMI and JAAKKO SÄKÖ

HIIRSALMI, H. & SÄKÖ, J. 1985. **A Finnish strawberry variety 'Hiku'.** Ann. Agric. Fenn. 24: 179—182. (Agric. Res. Centre, Dept. Hort., SF-21500 Piikkiö, Finland.)

The strawberry breeding started in 1961 is beginning to give results that benefit practical cultivation. The crossing of the German variety 'Senga Sengana' with the Scottish variety 'Redgauntlet' has produced a selection that is so valuable for its culture properties that it has been released for sale. It has been given the variety name 'Hiku'.

The 'Hiku' is a good cropper. The amount of saleable yield has in the trials regularly been close to 200 kg/100 m^2. Regarding other properties as well this variety has proved valuable. Its berries are large and qualitywise first-rate. It has an open growth habit and thus its resistance to grey mould (*Botrytis cinerea*) is good. On the other hand, it is somewhat susceptible to mildew (*Sphaerotheca macularis* f.sp. *fragariae*). 'Hiku' must be classified a late variety under the conditions prevailing in Finland.

Index words: strawberry varieties, strawberry breeding.

In the course of decades the cultivation value of over one hundred strawberry varieties bred abroad has been worked out by the Department of Horticulture at the Agricultural Research Centre (MEURMAN 1947, SÄKÖ 1959, 1968, SÄKÖ and HIIRSALMI 1976, SÄKÖ, RYYNÄNEN and LAURINEN 1979). However, out of these just a few have qualified for practical cultivation in Finland. The principal varieties are 'Senga Sengana' and 'Zefyr'.

Most foreign strawberry varieties do not under the temperature and light conditions in Finland produce the result that is required for profitable cultivation. The emergence of a variety like 'Senga Sengana', which has attained practical cultivation in many different countries, is extremely rare. The further the breeding is developed in other countries the further it simultaneously becomes specialized and the harder it gets to find foreign varieties adaptable to Nordic climatic conditions. Hence the domestic breeding work, which takes into account the local requirements in the different parts of the country, has become all the more important. Systematic breeding of the strawberry has in Finland been carried out since 1961 in the Department of Horticulture at Piikkiö (HIIRSALMI 1969).

Aims

The aim in the strawberry breeding has been to produce cultivationwise safe varieties, whose berries are suited for use fresh, for freezing as well as industrial needs. This means that special attention must be paid to crop and berry size as well as berry firmness, to transport and freezing durability, to acid, aroma and vitamin content, to flavour, colour and shape. Additional important qualities include resistance to various diseases and pests. Among these are especially grey mould (*Botrytis cinerea*) and mildew (*Sphaerotheca macularis* f.sp. *fragariae*) plus the strawberry mite (*Tarsonemus fragariae*) and eelworm (*Aphelenchoides fragariae*). In recent years the breeding has also taken into account the requirements introduced by mechanized harvesting methods. The prime requisite would here be as far as possible simultaneous ripening of the berries.

Development of selections

Within the framework of the breeding programme for the planned strawberry the Department of Horticulture has so far made 177 crossings and 27 self-pollinations. The 1961—1980 progenies, a total of approximately 7300 seedlings, have been graded in the trial field. Out of these 347 promising individuals were chosen for clone trials, and again of these 69 for selections in comparative trials with the varieties 'Senga Sengana' and 'Zefyr'.

The results of these comparative trials with the strawberry selections have made the basis for the final choice of those selections, which for certain properties are superior to the varieties grown and thus can be considered when nominating new varieties. So far 18 such selections have been picked out. However, only very rarely indeed is some selection so valuable that accepting it for cultivation as a variety is justified.

Out of all the selections so far developed in the Department of Horticulture selection 71041117, from the crossing 'Senga Sengana' × 'Redgauntlet' made in 1971, has indisputably been the best cropper. The total yield calculated for it as a seedling was 248 kg/100 m^2 and in the clone trials the corresponding figure was 160 kg/100 m^2. In the comparative trials undertaken in the Department of Horticulture

Table 1. Results of strawberry variety trials in 1979—1981 in the Department of Horticulture at the Agricultural Research Centre

Variety Selection	Saleable yield		Total yield kg/100 m^2				Out of total yield			Berry weight
							Small	Mouldy	Crop for 2 first weeks	
	kg/100 m^2	%	1979	1980	1981	$\bar{x}$	%	%	%	g
71041117 (= Hiku)	170	87	111	216	259	195	6	7	58	14,2
Senga Dulcita	127	75	166	116	228	170	6	19	60	14,2
Senga Gourmella	111	87	76	94	212	127	5	8	67	11,9
65029001	110	92	76	137	146	120	6	2	79	12,0
Zefyr	107	91	61	117	176	118	7	2	89	10,0
Senga Sengana	101	80	93	111	178	127	8	12	61	10,1
Tamella	93	83	81	114	140	112	7	10	58	14,0
Senga Litessa	83	80	97	74	138	103	4	16	72	13,6
Kristina	80	78	63	121	127	107	20	2	82	7,0
Junimorgen	68	89	54	91	83	76	7	4	70	10,6
Hella	62	87	48	87	81	72	9	4	81	8,5

Selections: 65029001 = Pocahontas × Lihama
71041117 = Senga Sengana × Redgauntlet

the saleable yield of selection 71041117 amounted to 190 kg/100 m^2 and in the variety trials (Table 1) to 170 kg/100 m^2. Also as regards other properties said selection has proved valuable. The berries are quite large and first-rate qualitywise although not as dark as the 'Senga Sengana' berries. The selection has an open growth habit and hence its resistance to grey mould is better than that of the 'Senga Sengana' variety.

On the other hand, it is somewhat susceptible to mildew. In the grading done in the summer of 1984 the mildew resistance on the ten-grade scale was 9,0 for 'Senga Sengana' and 3,7 for 'Zefyr' respectively. For selection 71041117 the mildew resistance value has been 7,0. Selection 71041117 has proved to be vigorous, among other things by overwintering well in all trials, including the winters 1982—83 and 1983—84 when most varieties and selections were severely damaged due to ice-scorching.

Selection 71041117 has been found so valuable for its culture properties that it has been released for sale. It was given the variety name 'Hiku'.

Description of the 'Hiku' variety

The strawberry variety 'Hiku' was in 1971 chosen from among the progeny of the crossing 'Senga Sengana' × 'Redgauntlet' made in the Department of Horticulture at the Agricultural Research Centre at Piikkiö. Its various properties have features that suggest either of its progenitors. Yet concerning several qualities it is clearly intermediary.

This variety forms a vigorous, high and quite open growth structure. Its upright sturdy leaf stalks are tall. The leaflets are medium-sized and a palish green in colour, especially the underside is tinged a blue-grey. The flowering is largely protected by the foliage. As the berries ripen, however, the clusters bend sideways so that a large part of the crop is easily reached for picking.

Due to the open growth habit of the variety the airiness of the growth structure promotes the resistance to disease, particularly to grey mould (*Botrytis cinerea*). In the trials the resistance to grey mould and mildew (*Sphaerotheca macularis* f.sp. *fragariae*) of this variety has been found to be satisfactory. The proportion of mouldy berries in the whole crop has ranged from 0 to 7 percent depending on the temperature and humidity of the growth period. The 'Hiku' also seems to stand the winter well, even in areas suffering from ice-scorching.

The 'Hiku' must be classified a late variety, which will hardly do for growing in the northernmost parts of Finland. It is a very heavy cropper. The saleable yield has in the trials by the Department of Horticulture most often amounted to nearly 200 kg/100 m^2, sometimes even more. Some years occasional trial squares have yielded even over 300 kg/100 m^2. The berries are cone-shaped or often also rounded oblongs and rather large. On an average the berry weight has been over 13 g, although under dry conditions it may remain under 10 g. The berries are quite firm and the colour scarlet. The berry flesh is pink.

The 'Hiku' variety's berries are pleasantly flavoured, sweetish and aromatic. They are well suited for use fresh and for freezing, and presumably also for the processing industry.

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SELOSTUS

Suomalainen mansikkalajike 'Hiku'

HEIMO HIIRSALMI ja JAAKKO SÄKÖ

Maatalouden tutkimuskeskus

Maatalouden tutkimuskeskuksen puutarhaosastolla vuodesta 1961 lähtien käynnissä olleen mansikan jalostusohjelman puitteissa on tähän mennessä tehty 177 risteytystä ja 27 itsepölytystä. Vuosien 1961—1980 jälkeläistöt, yhteensä noin 7300 siementainta, on arvosteltu koekentällä. Niistä on valittu 347 lupaavaa yksilöä kloonikokeisiin, ja niistä edelleen 69 jalosteiksi vertailukokeisiin. Kaikkein parhaiden jalosteiden, tähän mennessä 18 jalosteen, viljelyarvo on testattu lajikekokeissa.

Jaloste 71041117, joka on peräisin risteytyksestä 'Senga Sengana' × 'Redgauntlet', on kaikkein satoisin. Myyntikelpoisen sadon määrä on puutarhaosaston kokeissa ollut useimmiten lähes 200 kg/100 m^2. Muiltakin ominaisuuksiltaan jaloste on osoittautunut arvokkaaksi. Sen marjat ovat varsin kookkaita ja laadukkaita. Kasvutavaltaan se on ävoin ja harmaahomeenkestävyys näin hyvä. Härmätaudille se sen sijaan on jossakin määrin altis. Marjojen myöhäisen kypsymisajankohdan — lähes samanaikainen 'Senga Senganan' kanssa — vuoksi se tuskin soveltuu viljeltäväksi pohjoisimmassa Suomessa. Jaloste 71041117 on laskettu kauppaan lajikenimellä 'Hiku'.

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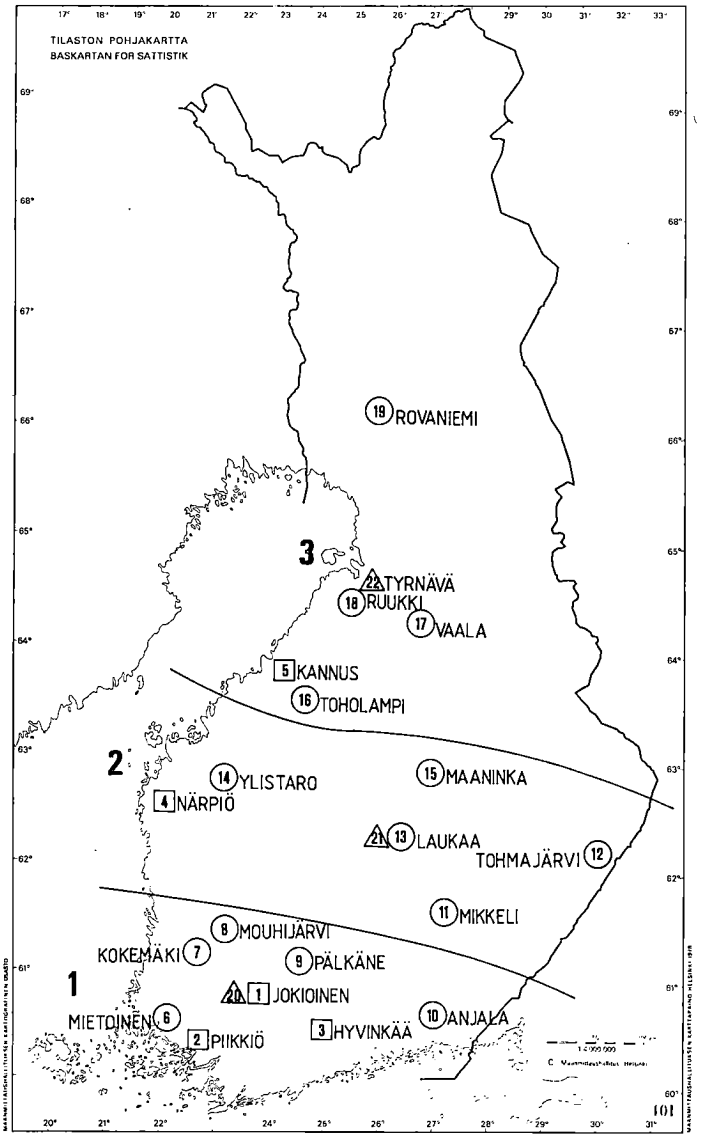

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