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ANNALES AGRICULTURAE FENNIAE, VOL. 23: 135—144 (1984)

Seria AGRICULTURA N. 70—Sarja PELTOVILJELY n:o 70

# ACCLIMATIZATION OF QUINOA (*CHENOPODIUM QUINOA*, Willd) AND CANIHUA (*CHENOPODIUM PALLIDICAULE*, Aellen) TO FINLAND

MIGUEL L. CARMEN

CARMEN, M. L. 1984. **Acclimatization of Quinoa (*Chenopodium quinoa*, Willd) and Canihua (*Chenopodium pallidicaule*, Aellen) to Finland.**
Ann. Agric. Fenn. 23: 135—144. (Agric. Res. Centre, Inst. Plant Husbandry, SF-31600 Jokioinen, Finland.)

Quinoa (*Chenopodium quinoa,* Willd) and canihua (*Chenopodium pallidicaule,* Aellen), high quality Andean protein crops, were sown in the field at two localities, Jokioinen (latitude 60° 49' N) and Ruukki (latitude 64° 41' N) to study their degree of acclimatization to Finland. Seventy-six ecotypes of quinoa (including four varieties) and thirty-five ecotypes of canihua were tested in Jokioinen.

In Ruukki, nine quinoa ecotypes (including two varieties), and six canihua ecotypes were tested. The grains of these crops have a good balance of essential amino acids, and their lysine content is about twice that of wheat. About fifty of the quinoa ecotypes and thirtyfive canihua ecotypes produced matured seed in Jokioinen. Five canihua ecotypes matured, and the Sajama quinoa variety come close to maturity in Ruukki. Selection of the earlier maturing genetic material has been performed to continue the study of their adaptation to the different agro-ecological conditions of Finland.

Index words: acclimatization, *Chenopodium quinoa, Chenopodium pallidicaule.*

## INTRODUCTION

### General information

Quinoa (*Chenopodium quinoa*, Willd) and canihua (*Chenopodium pallidicaule*, Aellen) are crops which have been cultivated in the Andean regions of South America since long before the Inca Empire.

Archaeological studies reported by UHLE (1919) and NUÑEZ (1970) cited (p. 12) in TAPIA et al. (1979), have shown that the quinoa was already known in 5000 and 3000 B. C., respectively. Quinoa is currently grown for its grain in the following South American countries: Argentina (North), Chile (Central and North), Bolivia, Peru, Ecuador and Colombia. Canihua cultivation is concentrated in the high plateau of Peru and Bolivia and in the highland region of Cochabamba (Bolivia).

Quinoa and canihua are normally grown at altitudes of 2000 to 4000 m above sea level. They are frost and drought resistant, and are able to grow on poor soils with an annual rainfall of 300—400 mm. These crops grow perfectly at high altitudes where it is not possible to grow maize, and mature in four to seven months depending upon the variety (or ecotype).

The quinoa is 0,5—2,0 m high with large panicles of 1,8—2,2 mm long seeds produced at the end of the stem. The canihua is 0,2—0,7 m high and its seeds are 1,0—1,2 mm long. The grains of both crops are edible, and are important foods in the Andean regions. Their grain yields vary from 1 to 3 ton/ha according to the variety and the level of technology.

Saponins (glucosides) in the seed coat produce a bitter taste. However, these products can be easily removed mechanically or by washing, methods already in use (TAPIA et al. 1979). The saponins contents vary between ecotypes, and in some of them it is very low. Loamy soils with good drainage are the most suitable for guinoa and canihua. They are grown using both traditional and modern technology. Combine harvesters have been used with guinoa (VALIENTE et al. 1981).

## Nutritive value

The grains of quinoa and canihua have a high food value. The high guality of their proteins in particular has been reported. Tables 1 and 2 show the nutrient and essential amino acid compositions, respectively (WHITE et al. 1955). In general, their protein contents are similar or higher than those of wheat or oats. Their fat contents are similar to that of oats, but higher than those of wheat, maize, and rice. They have higher contents of calcium, iron and vitamin B complex than wheat, maize, oats and rice. The lysine content of quinoa and canihua is about twice that of wheat and is higher than that of maize, oats and rice. They also have higher contents of arginine, histidine, threonine, and isoleucine than wheat. With the exception of phenylalanine, their contents of the other essential amino acids — tryptophan, methionine, leucine, and valine — are about the same as those of wheat. WHITE at al. (1955) found in rat studies that the quinoa and canihua proteins produced weight gains equal to or superior to those obtained with dried whole milk at equal levels of protein intake. Furthermore mixtures of quinoa and milk did not produce greater gains than quinoa alone. This result was confirmed by QUIROS—PEREZ and ELVEHJEM (1957) who reported from rat studies that guinoa alone produced as good a growth rate as a combination of two thirds of the protein from quinoa and one third from casein. MAHONEY (1975) showed that a cooked quinoa flour diet improved rat weight

Table 1. Nutrient composition of quinoa and canihua grains [1] WHITE et al. 1955

(per 100 grams)

| Nutrient | Canihua | Quinoa |
|---|---|---|
| Protein (N x 6,25), g | 14,1 | 11,0 |
| Fats (ether soluble), g | 4,1 | 5,3 |
| Fiber, g | 10,7 | 4,9 |
| Ash, g | 4,6 | 3,0 |
| Calcium | 126,0 | 131,0 |
| Phosphorus, mg | 461,0 | 424,0 |
| Iron, mg | 18,8 | 6,8 |
| Thiamine, mg | 0,78 | 0,52 |
| Riboflavin, mg | 0,55 | 0,31 |
| Niacin, mg | 1,34 | 1,60 |

[1] All values corrected to 12 % moisture content.

Table 2. Essential amino acid compositions of quinoa, canihua and whole wheat. (Calculated to 16,0 grams of nitrogen)
WHITE et al. 1955[1]

| Amino acid | Quinoa % | Canihua % | Whole wheat % |
|---|---|---|---|
| Arginine | 7,4 | 7,9 | 4,3 |
| Histidine | 2,7 | 2,5 | 2,1 |
| Lysine | 6,6 | 6,0 | 2,7 |
| Tryptophan | 1,1 | 0.8 | 1,2 |
| Phenylalanine | 3,5 | 3,6 | 5,1 |
| Methionine | 2,4 | 1,8 | 2,5 |
| Thereonine | 4,8 | 4,8 | 3,3 |
| Leucine | 7,1 | 5,8 | 7,0 |
| Isoleucine | 6,4 | 6,8 | 4,0 |
| Valine | 4,0 | 4,6 | 4,3 |

[1] BLOCK and BOLLING 1951 (quoted by WHITE et al. p. 533)

grain by a factor of fours over a wheat diet; moreover the uncooked quinoa flour diet improved rat weight gain by a factor of 1,5 over the wheat diet. On the basis of the NEG (nitrogen efficiency for growth) value, the proteins of uncooked quinoa and casein can be considered similar. The NEG can be improved by forty per cent without significantly changing its amino acid composition by cooking the quinoa. The weight gain obtained with the wheat flour diet was improved by 111 % by replacing twenty per cent of wheat flour with quinoa flour.

### Uses

Quinoa is used in different ways, its main use being in soups. Quinoa and canihua grain have no gluten and so they cannot be used alone for bread-making. Quinoa flour can be mixed with wheat flour in the preparation of bread and noodles, the proportion of quinoa flour varying between ten and forty per cent (LUNA DE LA FUENTE 1957). High protein cakes and biscuits can be produced by mixing up to 60 % quinoa flour with wheat flour (WEBER 1978). Quinoa flour can be used in baby food (BARRIOS 1978). Flakes, similar to corn flakes, have also been prepared from quinoa. Quinoa flour has given good results in feeding trials with chickens, pigs and ruminants (TAPIA et al. 1979). Stacks, chaff, gleanings, and bran are used to feed ruminants. The saponins obtained as a by-product in the processing of quinoa can be utilized in the preparation of products for photography, cosmetics (shampoo), and the pharmaceutical industry (synthetic hormones) (TAPIA et al. 1979). Canihua has similar uses.

## MATERIAL AND METHODS

### Climatic requirements

Temperature, precipitation, and radiation are three of the most important climatological factors which affect plant growth. The author calculated the average total values of temperature (total sum of degrees-day, °C), precipitation, and radiation (duration of bright sunshine hours) corresponding to the growing period of quinoa and canihua in Puno, Peru (Refs. to Peruvian meteorological publications). Puno is one of the most important areas for these crops in South America. Also, the average totals of these factors were calculated for the growing period of annual crops in Finland (refs. to Finnish meteorological publications). Evaluation of the results showed that the regions situated below latitude 65° N in Finland could satisfy the climatological requirements for growing short and some middle season varieties of quinoa and canihua. FULLER (1949), working with seed material from Bolivia, found out that *Chenopodium quinoa* is an indeterminate of day neutral species. The author has found no studies concerning the photoperiod requirements of canihua.

### Germ plasm selection

In March 1983 the author travelled to Puno, Peru in order to select the most suitable genetic material of quinoa and canihua for testing in Finland.

The guinoa and canihua genetic materials were selected at Tahuaco Agricultural Experiment Station (3 850 m above sea level, 150 km from the city of Puno), and Illpa Agricultural Experiment Station (3 815 m above sea level, 20 km from the city of Puno), respectively. Sixty-two ecotypes and four varieties out of 1025 quinoa entries in the Tahuaco Agricultural Experiment Station were selected by evaluation of field and germ plasm records. Included among this material were the following commercial varieties: Sajama, Cheweca, Kanccolla, and Blanca de Juli. The most promising ecotypes tested in the yield and frost resistance trials were also included. The criteria used in the selection of quinoa genetic material were: short growing period, high yield and white colour of the grain. Samples of the ten entries from the most promising variety and ecotype experiments were obtained from the Agricultural Experiment Station of the Technical University of the Altiplano (Camacani, Puno). An total of seventy—six entries of quinoa were selected. (These ecotypes are of Peruvian or Bolivian origin.)

The criteria used to select the 35 canihua ecotypes were: short growing period, high yield, and erect type of plant. These included two from the Agricultural Experiment Station of the Technical University of the Altiplano (Camacani, Puno). (These ecotypes are originally from Peru.)

## Field experiments

Two collections of germ plasm were carried out in 1983. One of them was conducted at the Finnish Agricultural Research Centre, Jokioinen (Latitude 60° 49' N, Longitude 23° 30' E) and the other at Ruukki Agricultural Research Station (Latitude 64° 41' N, Longitude 25° 06' E) (Figs. 1—3). The Jokioinen collection comprised seventy-six entries of quinoa (including four commercial varieties) and thirty—five entries of canihua. The Ruukki collection was composed of nine entries of quinoa (including two varieties) and six entries of canihua. These collections were seeded on May 10 and May 15 in Jokioinen and Ruukki, recpectively. Each entry was seeded in a plot of four ten-metre rows, and occupied a total area of fifteen square meters.

The collections required 111 and 15 plots without replications in Jokioinen and Ruukki, respectively. A 16-7-13 NPK fertilizer mixture was applied before seeding at the rate of 400 and 500 kg/ha in Jokioinen and Ruukki, respectively. The collection in Jokioinen grew on a clay soil, pH 6,5 and on fine sand, pH 5,7 in Ruukki. The plants were grown under rainfall conditions. The two central rows of each plot were thinned in order to retain ten plants per metre and a population of about 26700 plants per hectare.

Fig. 1 Quinoa and canihua germ plasm collection. Finnish Agricultural Research Centre (MTTK), Jokioinen 1983.

Fig. 2 Quinoa plants. Germ plasm collection at MTTK, Jokioinen 1983.

Fig. 3 Canihua plants. Germ plasm collection at MTTK, Jokioinen 1983.

Weeds were controlled manually and mechanically. No disease was observed. Insect control was applied only in Ruukki. The frosts observed from May to September in Jokioinen and Ruukki did not cause any damage to either the quinoa or the canihua. The following observations were recorded: germination, plant height, flowering, seed maturity, and insect and disease attack.

The entire collection in Ruukki was harvested on September 20; plant samples of quinoa and canihua were sent to the Institute of Plant Husbandry, Jokioinen, for study and evaluation. In Jokioinen, the canihua was harvested (manually and mechanically) between September 30 and October 13, while the selection of quinoa panicles was carried out in the field from October 8 to October 27, 1983.

## RESULTS

### Quinoa *(Chenopodium quinoa,* Willd)

### Jokioinen

The seventy-six ecotypes (including four commercial varieties) grew well under the long day conditions at Jokioinen. Some of the ecotypes even showed more vegetative development than in their natural environment. Average plant heigh among the ecotypes varied between 1,00 and 1,90 m. All ecotypes flowered, and fifty days after seeding all of them showed panicle initiation. The ecotypes which reached fifty per cent of anthesis early were 03-21-271, 03-21-284, 04-02-099 and 04-02-124.

Panicle size varied between and within the ecotypes: panicles up to 60 cm long were observed. A fully developed quinoa panicle is shown in Fig. 4 (04-02-342 ecotype). Fifty of the ecotypes produced some plants with fully matured seed in their panicles (Figs. 5 and 6). A total of 1700 panicles with varying amounts of fully matured seed were selected in the field (Fig. 7).

The commercial varieties Sajama, Kanccolla, and Blanca de Juli produced panicles with fully matured seed. Neither disease attack nor significant insect damage was observed in the ecotypes. The quinoa seed produced in Jokioinen showed ninety-four and one hundred per cent of germination on the sand and paper tests, respectively (04-02-288 ecotype).

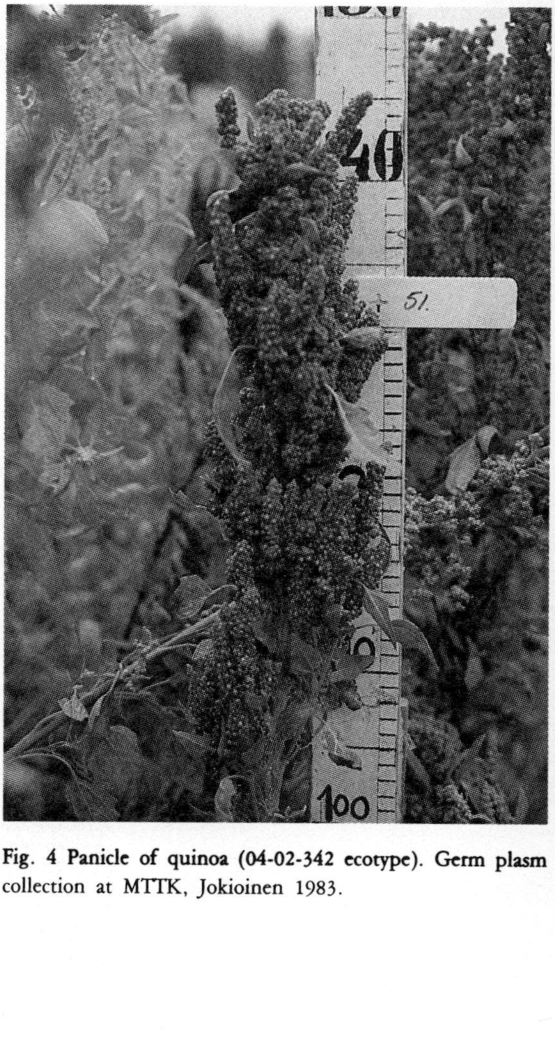

**Fig. 4 Panicle of quinoa (04-02-342 ecotype). Germ plasm** collection at MTTK, Jokioinen 1983.

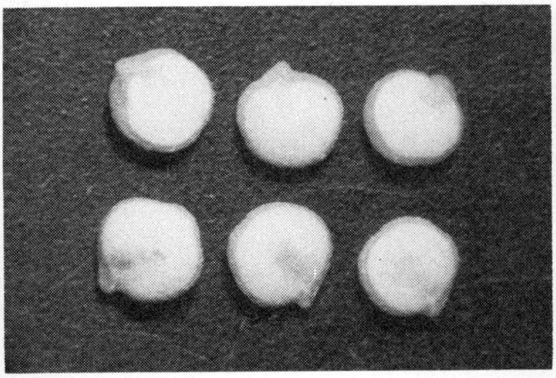

Fig. 6 Ripe grain of quinoa (Sajama variety). Germ plasm collection at MTTK, Jokioinen 1983.

Fig. 7 Selected panicles of quinoa. Germ plasm collection at MTTK, Jokioinen 1983.

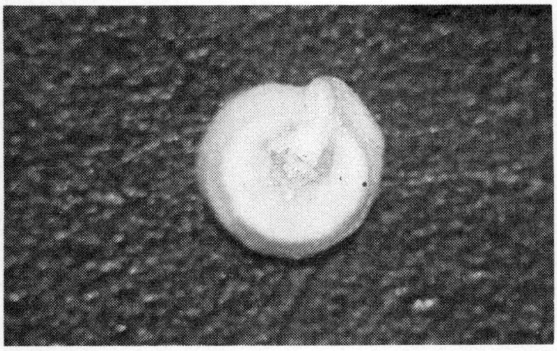

Fig. 8 Grain of quinoa (Sajama variety). Germ plasm collection at Ruukki Agricultural Experiment Station, Ruukki 1983.

## Ruukki

All nine ecotypes grew well under the climatic conditions in Ruukki. However they did show less vegetative development than in Jokioinen. The average plant height of the ecotypes varied between 0,55 and 0,88 m. Flowering was observed in all ecotypes. Sajama variety and 03-21-268 ecotype were the earliest in reaching anthesis. Furthermore, these ecotypes produced the biggest panicles which varied between 15 and 18 cm in length at harvest time. Sajama variety reached the end of the milk stage during the ripening process, while the 03-21-055 and 03-21-024 ecotypes reached only the pre-milk stage.

Figure 8 shows a quinoa grain of Sajama variety produced in Ruukki. Seed development was not observed in the other six ecotypes. It is necessary to point out that three of these ecotypes did not mature in Jokioinen either, and that more than forty of the ecotypes that matured in Jokioinen have not yet been tested in Ruukki.

No disease attack was observed. Insect damage by *Mamestra pisi* (broom moth), *Geometrid* (geometer moth), and *Lygus* sp. (caprid bug) were reported. This damage varied between 1 and 3 degrees (scale 0—3 degrees) and was controlled by spraying insecticide.

Fig. 5 Ripe grain of quinoa in the panicle chosen from the selected panicles dried out on shelves at MTTK, Jokioinen 1983.

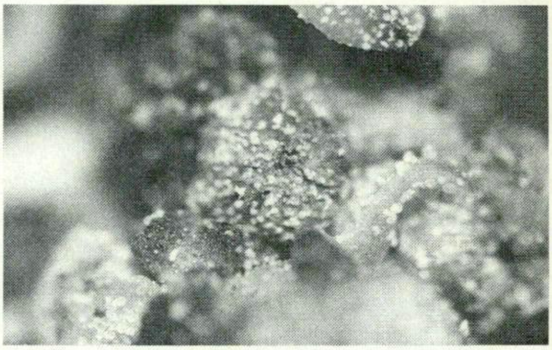

Fig. 9 Ripe grain of canihua in the panicle (03-21-095 ecotype). Germ plasm collection at MTTK, Jokioinen 1983.

## Canihua (*Chenopodium pallidicaule,* Aellen)

### Jokioinen

All thirty-five ecotypes grew well under the long day conditions of Jokioinen. Plant height varied among the ecotypes between 0,40 and 0,60 m. All thirty-five ecotypes flowered and produced fully matured seed (Figs. 9 and 10). The 03-21-095 ecotype was the earliest to mature, 112 days after seeding. The limited amount of mature seed produced varied between the ecotypes. Neither disease nor significant insect damage was observed. The canihua seed produced in Jokioinen showed ninety-seven per cent germination in the paper test (03-21-305 ecotype).

### Ruukki

Five out of six ecotypes tested grew well, and produced fully matured seed. The plants showed less vegetative growth than in Jokioinen. Average plant height varied between 0,26 and 0,31 m. No disease attack was observed. The insect damage varied among the ecotypes between 0 and 2 degrees (scale of 0—3 degrees), and was controlled by spraying insecticides. The canihua seed produced in Ruukki showed one hundred per cent germination in the paper test (03-21-305 ecotype).

Fig. 10 Grains of canihua (eighteen different ecotypes). Germ plasm collection at MTTK, Jokioinen 1983.

## DISCUSSION

The results obtained in 1983 have shown that quinoa (*Chenopodium quinoa,* Willd) and canihua (*Chenopodium pallidicaule,* Aellen) can grow and mature up to latitude 65° N in Finland (this includes the agro-ecological regions I, II, III, and half of region IV). As far as the author is aware, this is the first report showing that canihua can grow and mature in the field under long day conditions. Canihua produced fully matured seed in Jokioinen and Ruukki. Quinoa also matured in Jokioinen. It would be possible to produce fully matured quinoa plants further north by using the earlier genetic material available in the collection, and by using those which would be obtained in the coming years. The quinoa and canihua genetic material selected from the collections carried out in Jokioinen in 1983 could be used as a basic material to continue the selection of plants completely adapted to the agro-ecological conditions of Finland.

The high nutritional value of quinoa and canihua has been pointed out. These crops, once adapted in Finland, have a great potential as important sources of high quality plant protein for human and animal nutrition. Therefore, studies on crop adaption, and later on studies on crop management, crop improvement, and industrial utilization deserve continued interest in the Finnish agricultural research programme.

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## REFERENCES

ANON. 1966—1969. Measurements of radiation and bright sunshine 1957—1960, 1961—1962, 1963—1964, 1965—1966. Meteorol. Yearb. Finl. Vol. 57—60, 4., 61—62, 4., 63—64, 4., 65—66, 4., Helsinki.

— Resumen Mensual Meteorológico 1931—1934. Dirección de Agricultura y Ganaderia. Servicio Meteorológico Nacional. Lima, Perú.

— Boletin Anual Meteorológico 1941—1944. Dirección de Comunicaciones y Meteorología. Departemento de Meteorología. Lima, Perú.

— Boletin climatológico anual 1961—1963. Dirección General de Meteorología. Lima, Perú.

— 1965. Anuario Meteorológico. Dirección General de Meteorología. Lima, Peru.

BARRIOS, B. 1978. Mil delicias de la quinoa. Oruro, Bolivia, "Quelco". Cited in Tapia et al., p. 198. 1979.

FULLER, H. J. 1949. Photoperiodic responses of *Chenopodium quinoa,* Willd, and *Amarantus caudatus* L. Amer. J. Bot. 36: 175—180.

HELIMÄKI, U. I. 1967. Tables and maps of precipitation in Finland 1931—1960. Suppl. Meteorol. Yearb. Finl. 66, 2. 1966. Helsinki.

KOLKKI, O. 1966. Tables and maps of temperature in Finland. 1931—1960. Suppl. Meteorol. Yearb. Finl. 65, 1a. 1965. Helsinki.

LUNA DE LA FUENTE, R. & CHIRINOS M. F. 1957. Ensayo de panificación con mezclas de harina de trigo y quinua. Lima, Estacion Experimental La Molina. Informe Mensual No. 358 p. 7—8. Cited in Tapia et al. p. 198. 1979.

MAHONEY, A. W., LOPEZ, J. G. & HENDRICKS, D. G. 1975. An evaluation of the protein quality of quinoa. J. Agric. Food Chem. 23, 2: 190—193.

QUIROS-PEREZ, F. & ELVEHJEM, C. A. 1957. Nutritive value of quinoa proteins. J. Agric. Food Chem. 5, 7: 538—541.

ROSSI, V. 1976. Results of radiation measurements in Finland during the years 1958—1967. Suppl. Meteorol. Yearb. Finl. 69—70, 4. 1969—1970. Helsinki.

TAPIA, M., GANDARILLAS, H., ALANDIA, S., CARDOZO, A., MUJICA, A., ORTIZ, R., OTAZU, V., REA, J., SALAS, B. & ZANABRIA, E. 1979. Quinua y Kaniwa cultivos andinos. Centro Internacional de Investigaciones para el Desarrollo (CIID), Instituto Interamericano de Ciencias Agrícolas (IICA). Editorial IICA.

VALIENTE, R., ETCHEVERS, J. & HERTZ, E. 1981. Efecto de sistemas de preparación de suelo, siembra y cosecha sobre los rendimientos de guinoa. Agricultura Tecnica, Chile. 41, 3: 121—126.

WEBER, E. J. 1978. The Inca's ancient answer to food shortage. Nature 272: 486.

WHITE, P. L., ALVISTUR, E., DIAS, C., VINAS, E., WHITE, H. S. & COLLAZOS, C. 1955. Nutrient content and protein quality of quinoa, and canihua, edible seed products of the Andes Mountains. J. Agric. Food Chem. 3, 6: 531—534.

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# SELOSTUS

## *Chenopodium quinoa,* Willd ja *Chenopodium pallidicaule,* Aellen aklimoituminen Suomeen

MIGUEL L. CARMEN

Maatalouden tutkimuskeskus

*Chenopodium quinoa* (quinoa) ja *Chenopodium pallidicaule* (canihua) ovat Andien vuoristossa Etelä-Amerikassa viljeltyjä kasveja. Ne ovat yksivuotisia ja tuottavat runsaasti hyvälaatuista valkuaista sekä ihmisravinnoksi että kotieläinten rehuksi.

*C. quinoa* kasvaa 0,5—2,0 m:n ja *C. pallidicaule* 0,2—0,7 m:n korkuiseksi. Kumpikin laji kasvattaa varren latvaan kookkaita röyhyjä, joihin kehittyy pieniä, 1,0—2,2 mm:n läpimittaisia siemeniä (kuvat 4 ja 5). Siemenet ovat syötäviä ja niiden valkuaisen laatu on etenkin niiden runsaan lysiinipitoisuuden vuoksi parempi kuin korsiviljojen (taulukot 1 ja 2).

Vuonna 1983 kirjoittaja hankki Suomeen Perusta *C. quinoan* ja *C. pallidicaulen* jalostusaineistoa, edellistä 76 ekotyyppiä (jalostetta ja linjaa) ja jälkimmäistä 35 ekotyyppiä, niiden viljelymahdollisuuksien kokeilemiseksi Suomen ilmanalassa. Pääosa aineistosta kylvettiin Jokioisiin (60° 49' N) aitosavimaalle 10.5. Muutamia ekotyyppejä kylvettiin lisäksi Ruukkiin (64° 41' N) hietamaalle 15.5. Canihua korjattiin Jokioisissa 30.9.—27.10. ja quinoan röyhyjen valinta tehtiin 8.10.—27.10.1983. Ruukissa kasvit korjattiin 20.9.

Jokioisissa noin 50 *C. quinoan* ja 35 *C. pallidicaulen* ekotyyppiä tuotti tuleentuneita siemeniä. Ruukissa tuleentui viisi *C. pallidicaule* ekotyyppiä ja lisäksi yksi quinoa lajike (Sajama) ehti lähes tuleentuneeksi. Kasveissa ei todettu hallan eikä kasvitautien aiheuttamia vioituksia, mutta Ruukissa tuhoeläintorjunta oli tarpeen.

Tulokset osoittavat, että *C. quinoa* ja *C. pallidicaule* saattavat menestyä ja tuottaa tuleentunutta satoa pitkän päivän olosuhteissa aina 65° N leveysasteelle saakka. Suomen olosuhteissa viljeltäväksi soveltuvien lajikkeiden kehittämiseksi olisi kuitenkin tehtävä lisävalintaa ja risteytyskokeita Jokioisissa kesällä 1983 valikoidulla, aikaisin tuleentuvalla geeniaineistolla.

ANNALES AGRICUTULRAE FENNIAE, VOL. 23:145—157 (1984)

Seria AGROGEOLOGIA ET -CHIMICA N. 128 — Sarja MAA JA LANNOITUS n:o 128

# VARIATIONS IN YIELDS OF SPRING WHEAT, BARLEY AND OATS AS A CONSEQUENCE OF SOWING TIME DURING THE PERIOD 1970—1979 ON THREE SOIL TYPES

SIMO KIVISAARI

KIVISAARI, S. 1984. **Variations in yields of spring wheat, barley and oats as a consequence of sowing time during the period 1970—1979 on three soil types.** Ann. Agric. Fenn. 23: 145-157. (Agric. Res. Centre, Inst. Agric. Chem. Phys., SF-31600 Jokioinen, Finland.)

The effect of sowing time on the yields of spring wheat, barley and oats was studied in a ten-year trial at Tikkurila, southern Finland. Six different sowing times at roughly four-day intervals were studied. The first seed was sown immediately after the soil had dried sufficiently for cultivation.

The second or the third sowing time appeared to be the most suitable in general, but there were great variations between the years depending on the weather conditions and soil type. Very early sowing did not yield the best results, but in a dry year very late sowing could be even more detrimental.

With respect to giving good yields, silty clay soil was more sensitive to dry periods than sandy clay or clay loam soil. The reduction in yields could be very sharp, especially in dry years, and yields decreased with advanced sowing time. It was possible to obtain good yields from sandy clay soil even in dry years and despite late sowing.

The growing time was unaffected by the sowing time. There were great differences between different years: in dry years the growing time was shorter than in wetter years. In dry years, the growing time was short but the yield was often low, too. In years with enough rain the growing time was longer and the yields could be better, too. Rain in June, in particular, appeared to increase crop yields.

Index words: wheat, barley, oats, sowing time, growing time, sandy clay, clay loam, silty clay.

## INTRODUCTION

A great variation in spring cereal yield is typical of Finnish climatic conditions (POHJANHEIMO and HEINONEN 1961, POHJANHEIMO 1965, MUKULA 1984). However, variations in yields are often accompanied by variations in quality (KONTTURI 1979). The main reasons for these have usually been the dry periods of spring and early summer causing poor germination and sprouting (KRITZ 1983). The detrimental effect of dry weather becames particularly obvious in silty soils. Irrigation has proved to be a beneficial procedure for increasing yields and improving quality under such conditions (POHJANHEIMO and HEINONEN 1960, ELONEN et al. 1967, KIVISAARI and ELONEN 1974).

Because of the usual dry period of late spring and early summer it is reasonable to attempt to derive as much benefit as possible from the moisture existing in the soil from the thawed snow. The easiest method is to start sowing as early as possible; the two most important criteria are then of course, the state of the seed bed and soil temperature. In order to find the optimum sowing time a long-term field trial was started at the Agricultural Research Centre in Tikkurila in 1970. The experiment lasted for ten years.

## MATERIAL AND METHODS

**Time of sowing:** There were six different sowing times.

| Sowing | Name | average sowing time |
|---|---|---|
| 1. | very early sowing | 2.5. |
| 2. | early sowing | 5.5. |
| 3. | early normal sowing | 9.5. |
| 4. | late normal sowing | 14.5. |
| 5. | late sowing | 19.5. |
| 6. | very late sowing | 23.5. |

Very early sowing was done as soon as the top soil had dried sufficiently that it could be cultivated and a reasonable seed bed achieved. The following sowing times were at about four-day intervals. In practice, within the ten-year period the average date of the first sowing was May 2, and that of the sixth sowing was May 23. There was rather a lot of variation, of course, between these dates each year; the first varied from April 22 to May 10, and the last from May 19 to May 28.

**Soil type:** There were three different soil types in the trial. Their particle size compositions and organic matter contents were:

| | Clay <2 µm | Silt 2—20 µm | Fine sand 20—200 µm | Sand >200 µm | Org. matter % |
|---|---|---|---|---|---|
| Sandy clay | 36 | 18 | 36 | 10 | 5,7 |
| Clay loam | 41 | 26 | 29 | 4 | 6,6 |
| Silty clay | 42 | 37 | 16 | 5 | 5,7 |

The trials were on the same sites throughout the entire ten-year period.

**Crops:** The crops grown were spring wheat, barley and oats. The varieties of wheat were: Svenno from Svalöv in 1970—1971 and Tähti from Jokioinen in 1972—1979. The variety of barley was Pomo, a six row variety from Jokioinen. The varieties of oats were: Pendek from Holland in 1970 and Ryhti from Jokioinen in 1971—1979.

**Preparation of the seed bed:** The plots were ploughed in autumn. The ploughed fields were cultivated two or three times with an S-spring harrow in spring to a depth of about 3—6 cm.

**Sowing:** A combined drilling machine was used for sowing. The depth of seed placement at the first and second sowing was 3—5 cm, at the third and fourth 5—6 cm and at the last two 6—7 cm. The depths of fertilizer placement were 3 to 4 cm deeper than the sowing depths.

The seed rates were 700 germinating seeds/m$^2$ for wheat, 500 seeds/m$^2$ for barley and 600 seeds/m$^2$ for oats.

The quantity of fertilizer (20-4-8) was 600 kg/ha, corresponding to 120 kg N/ha.

### Climatic conditions

During a 'normal' year it is typical of the Finnish climate that the last two weeks of May and the beginning of June are dry. In some areas the lack of precipitation can be very detrimental to the growth of cereals. However, during the last ten years the rainfall has often been sufficient to ensure good crop growth.

## Temperature

The mean temperature of the ten-year period under study was normal (Table 1). The coldest years were 1976, 1977 and 1978 and the warmest 1972 and 1975, but the differences between the mean temperatures were not large. Within the months, however, there were rather large differences between the mean temperatures; the coldest May was in 1974 and the warmest in 1975, the difference being as much as 4,5 °C. It is obvious that big a difference will affect the warming of the seed bed and thus the germination and sprouting of the crop. There were also large differences between years in the mean temperatures in June and July.

## Precipitation

The variations in rainfall in summer were large. On average, the ten-year period 1970—1979 was somewhat drier than the thirty-year period 1931—1960, which corresponds to the 'normal' situation. However, in 1972 and 1978 the precipitation was well above the mean value of 305 mm (386 mm and 346 mm, respectively), but in neither of these cases was the rainfall distributed evenly: the heaviest rains were in August, and the other months were drier.

The driest growing seasons were 1971, and 1975 when the rainfall was as little as 205 mm in the entire five-month period. This is almost one half of that of the rainiest summer (1972) and only slightly more than that of the rainiest month — August — in that particular year.

Table 1. The temperatures and precipitation in Tikkurila during the months from May to September.

| | Month | | | | | |
|---|---|---|---|---|---|---|
| Year | V | VI | VII | VIII | XI | Mean |
| | | | Temperature °C | | | |
| 1970 | 9,5 | 16,7 | 16,4 | 15,4 | 9,8 | 13,6 |
| 1971 | 10,5 | 14,1 | 17,0 | 15,5 | 8,8 | 13,2 |
| 1972 | 9,3 | 16,5 | 20,0 | 16,6 | 10,3 | 14,5 |
| 1973 | 10,2 | 17,0 | 20,1 | 15,0 | 7,4 | 13,9 |
| 1974 | 7,2 | 14.6 | 15,9 | 14,7 | 12,4 | 13,0 |
| 1975 | 11,7 | 13,6 | 17.8 | 16,3 | 13,0 | 14,5 |
| 1976 | 10,8 | 13,0 | 15,6 | 14,8 | 7,7 | 12,4 |
| 1977 | 9,6 | 14,2 | 14,6 | 14,4 | 8,0 | 12,2 |
| 1978 | 10,3 | 14,6 | 14,9 | 14,3 | 9,1 | 12,6 |
| 1979 | 10,7 | 16,0 | 14,9 | 16,1 | 9,8 | 13,5 |
| 1970—79 mean | 10,0 | 15,0 | 16,7 | 15,3 | 9,6 | 13,3 |
| 1931—60 | 9,3 | 14,3 | 17,0 | 15,4 | 10,4 | 13,3 |
| | | | Precipitation mm | | | Total |
| 1970 | 25 | 13 | 120 | 31 | 78 | 267 |
| 1971 | 9 | 21 | 25 | 90 | 62 | 207 |
| 1972 | 37 | 44 | 87 | 174 | 44 | 386 |
| 1973 | 40 | 24 | 15 | 32 | 117 | 228 |
| 1974 | 39 | 48 | 63 | 69 | 91 | 310 |
| 1975 | 46 | 11 | 45 | 48 | 57 | 207 |
| 1976 | 27 | 39 | 64 | 48 | 59 | 237 |
| 1977 | 25 | 48 | 125 | 30 | 78 | 305 |
| 1978 | 5 | 44 | 64 | 127 | 106 | 346 |
| 1979 | 26 | 45 | 93 | 62 | 77 | 303 |
| 1970—79 mean | 28 | 33 | 71 | 71 | 77 | 280 |
| 1931—60 | 40 | 48 | 73 | 75 | 69 | 305 |

The most important months for germination and sprouting are undoubtedly May and June. The variation in the rainfall within those months was relatively large (Talbe 1). The driest May was in 1978, the precipitation being only 5 mm, while the wettest May was in 1975, the rainfall being nine times higher. The difference between the maximum and minimum rainfall in June was not so large.

## RESULTS

### Total yields

The sowing time had a great effect on the yields of spring cereals (Fig. 1). The most beneficial time was the second or third one. Very early sowing never gave the best yield, but the differences in the average yields between the first, second and third sowings were not large. Very late sowing appeared to be more detrimental than very early sowing; the latest sowing time resulted in the poorest average yields, in all of the crops and in all three soil types.

Soils containing large quantities of silt are known to have poor moisture characteristics. This is apparently the main reason why the poorest average yields were obtained from the silty clay

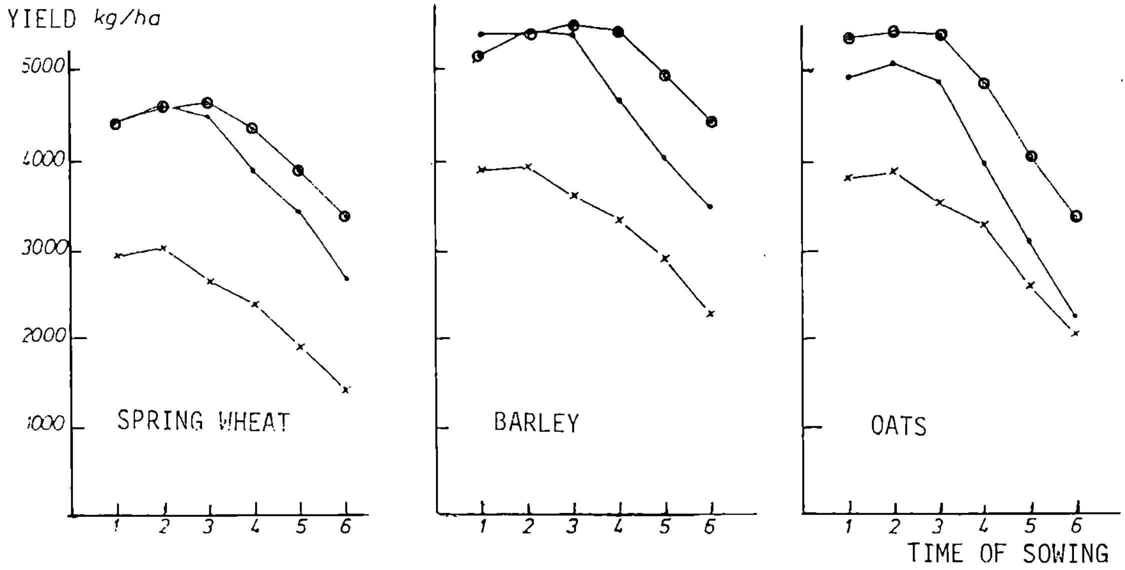


Fig. 1. The average grain yields of spring wheat, barley and oats on sandy clay (○ ——— ○), clay loam (• ——— •) and silty clay (x ——— x).

Table 2. The average yields (kg/ha) of crops calculated as means of the six sowings from the years corresponding to the maximum mean yield (Max.) and minimum mean yield (Min.). The corresponding year in parenthesis.

| | Wheat | | Barley | | Oats | |
|---|---|---|---|---|---|---|
| | Max. | Min. | Max. | Min. | Max. | Min. |
| Sandy clay | 5770(—74) | 2900(—79) | 6580(—76) | 3230(—73) | 7180(—76) | 3420(—78) |
| variation | 5980—<br>5340 | 3860—<br>1500 | 6920—<br>6220 | 4480—<br>1820 | 7820—<br>5900 | 5080—<br>720 |
| Caly loam | 5820(—74) | 2430(—73) | 6820(—76) | 2380(—73) | 6510(—76) | 2440(—78) |
| variation | 6200—<br>4700 | 3040—<br>1860 | 7260—<br>6160 | 3620—<br>960 | 7440—<br>4560 | 3860—<br>500 |
| Silty clay | 4140(—74) | 740(—73) | 5070(—76) | 700(—73) | 4890(—77) | 1140(—73) |
| variation | 4900—<br>3000 | 1200—<br>320 | 6440—<br>3340 | 1660—<br>120 | 5880—<br>3060 | 1780—<br>380 |

plots. Even the maximum yields were essentially lower than those from the clay loam and sandy clay. This is evident from the mean values of the whole material (Table 2). The variation between the maximum and minimum yieds was greater among the crops grown in the silty clay soils than those grown in clay loam or sandy clay soils.

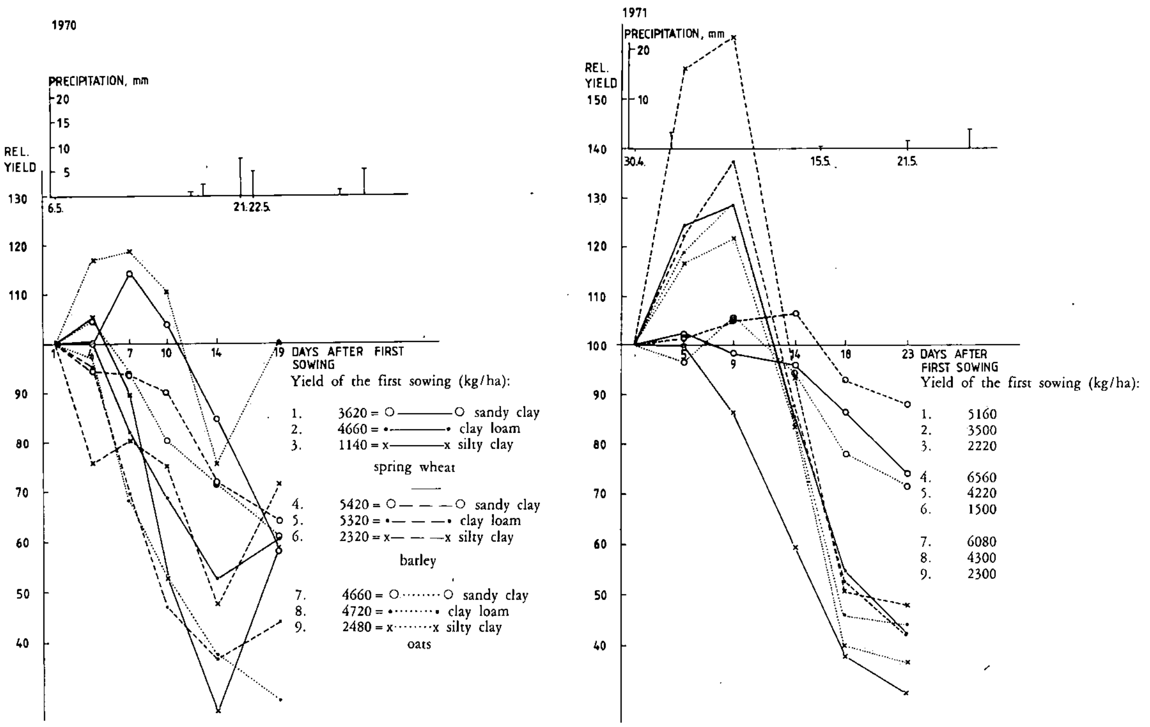
The figures show that, in Finland, the crop production in silty clay soils is rather uncertain under unfavourable weather conditions, but under certain favourable conditions it is possible to get good yields from them. The good yields, particularly those of 1974, 1976 and 1977, show that the soils have the potential for high yields, but the problem is apparently how to ensure that the high water retention capacity of silty soils can be utilized for the crop instead of allowing it to evaporate.

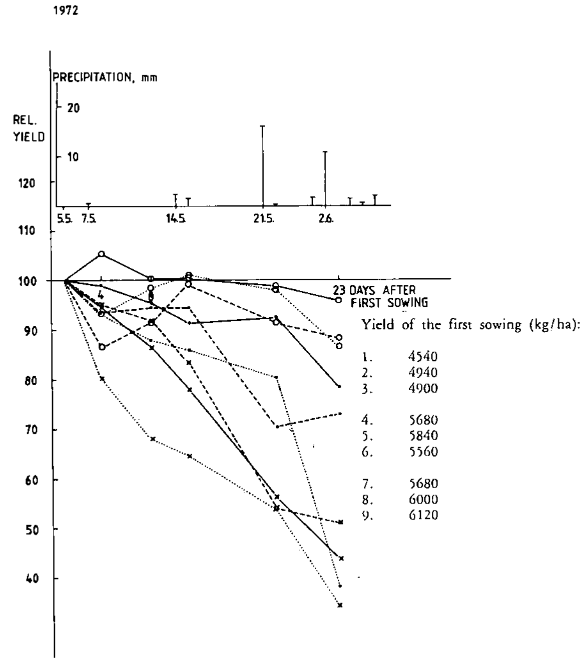
## Relative yields

The average values of yields calculated as means of the six sowings show the general tendency of the effects of sowing time.They do not, however, tell anything about the variations in the grain yields and the possible factors causing these variations. We can thus inspect the yields from each year, and analyse the factors affecting the yield formation. In the following (Figs. 2a—2j), the yields are presented as relative values. The yield (kg/ha) resulting from the first sowing is expressed as a value of 100 and the following yields are calculated on the basis of this. The precipitation during the sowing is also presented in the Figures.

**1970** (Fig. 2a). The total rainfall in summer 1970 was sightly less than 'normal' (Table 1). June was

Fig. 2a—2j. The relative yields of spring wheat, barley and oats according to the sowing time on the three soil types. The yield of the first sowing equal to 100. The precipitation during the sowing time presented above.



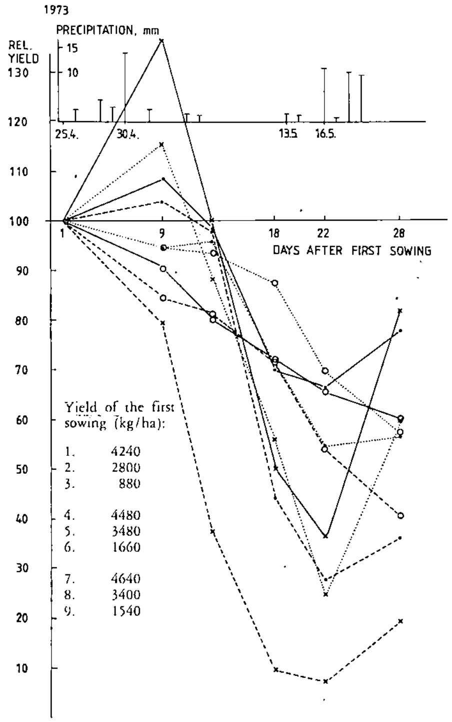


Yield of the first sowing (kg/ha):

1. 4540
2. 4940
3. 4900

4. 5680
5. 5840
6. 5560

7. 5680
8. 6000
9. 6120

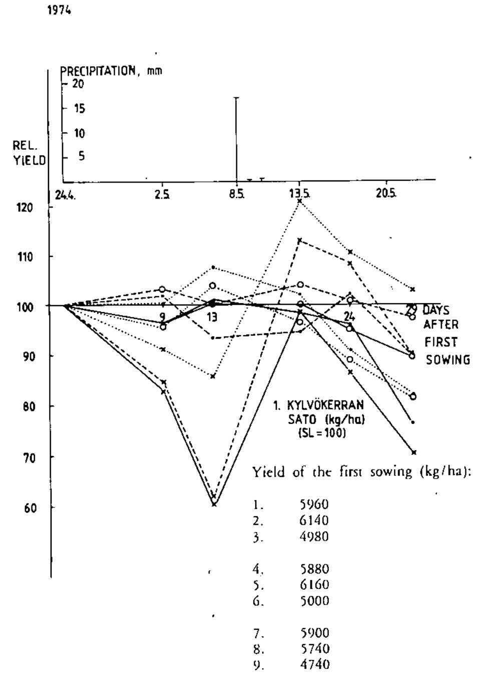


Yield of the first sowing (kg/ha):

1. 4240
2. 2800
3. 880

4. 4480
5. 3480
6. 1660

7. 4640
8. 3400
9. 1540

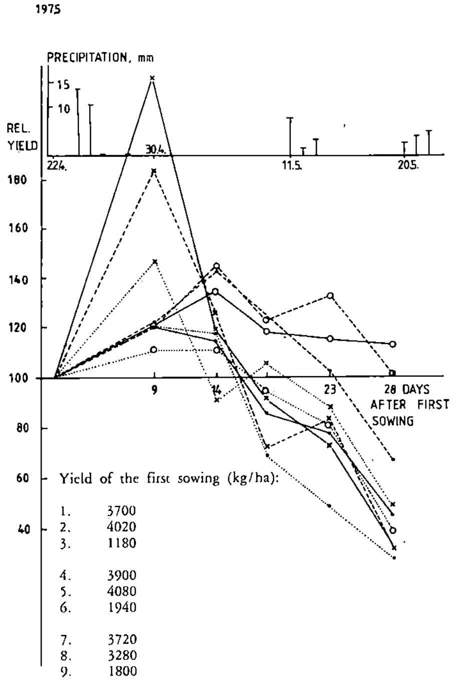


Yield of the first sowing (kg/ha):

1. 5960
2. 6140
3. 4980

4. 5880
5. 6160
6. 5000

7. 5900
8. 5740
9. 4740

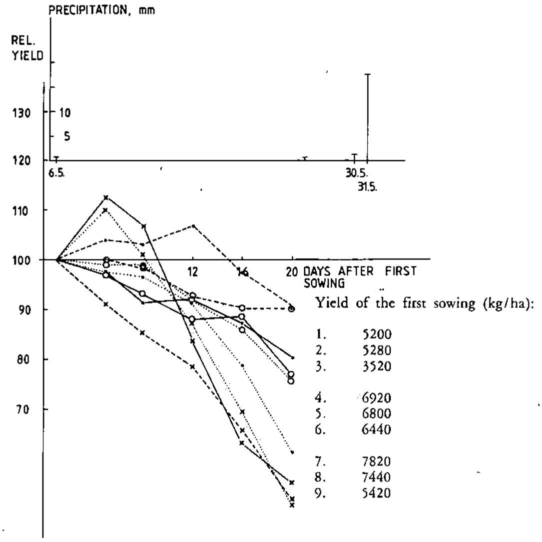


Yield of the first sowing (kg/ha):

1. 3700
2. 4020
3. 1180

4. 3900
5. 4080
6. 1940

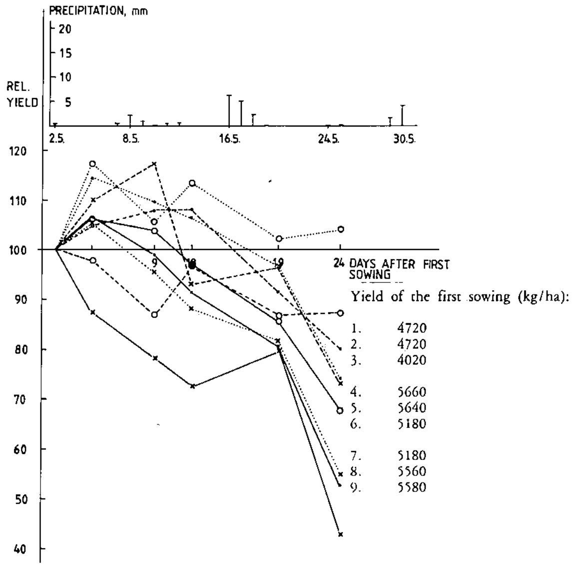
7. 3720
8. 3280
9. 1800



Yield of the first sowing (kg/ha):

| | |
|---|---|
| 1. | 5200 |
| 2. | 5280 |
| 3. | 3520 |
| 4. | 6920 |
| 5. | 6800 |
| 6. | 6440 |
| 7. | 7820 |
| 8. | 7440 |
| 9. | 5420 |

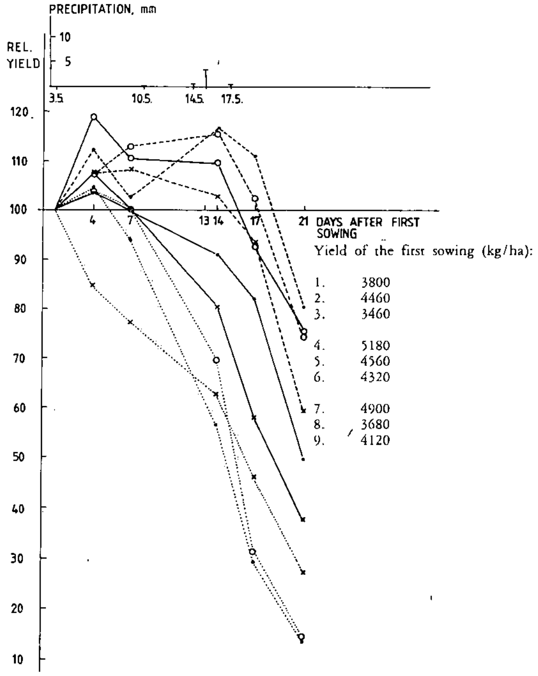
1977



Yield of the first sowing (kg/ha):

| | |
|---|---|
| 1. | 4720 |
| 2. | 4720 |
| 3. | 4020 |
| 4. | 5660 |
| 5. | 5640 |
| 6. | 5180 |
| 7. | 5180 |
| 8. | 5560 |
| 9. | 5580 |

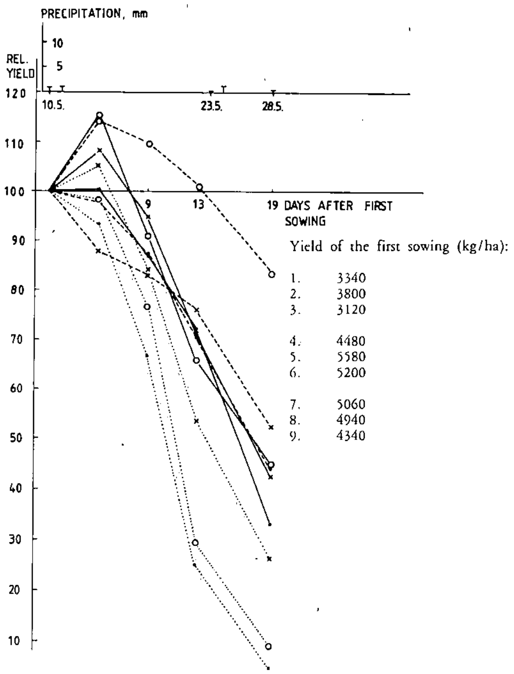
1978



Yield of the first sowing (kg/ha):

| | |
|---|---|
| 1. | 3800 |
| 2. | 4460 |
| 3. | 3460 |
| 4. | 5180 |
| 5. | 4560 |
| 6. | 4320 |
| 7. | 4900 |
| 8. | 3680 |
| 9. | 4120 |

1979



Yield of the first sowing (kg/ha):

| | |
|---|---|
| 1. | 3340 |
| 2. | 3800 |
| 3. | 3120 |
| 4. | 4480 |
| 5. | 5580 |
| 6. | 5200 |
| 7. | 5060 |
| 8. | 4940 |
| 9. | 4340 |

quite dry, only 13 mm of rain, while July was wet, 120 mm of rain. The scarcity of water in June obviously caused the especially low yields from silty clays.

The rains from 21.—22.5. caused some dispersing of the silty clay and thus some reduction in the yields of the fifth sowing. But meanwhile, the improved water content in the soil enhanced germination and sprouting of the sixth sowing.

**1971** (Fig. 2b). The 1971 growing season was the driest of the entire ten-year period, like 1975, the rainfall being only 207 mm. In spite of this the results from sandy clay were good but poor from the silty clay. The sowing time was very dry and it apparently caused a very sharp reduction in yields from silty clay and clay loam soils after the third sowing. The good yields from sandy clay soils are obviously due to its rather good water retention properties.

**1972** (Fig. 2c). Summer 1972 was the wettest during the entire ten-year period. The time of sowing was also rainy. The abundant rains obviously caused the relatively good yields from silty clay soils, particularly those from the first two sowings. The heavy rains on 21.5. and 26.5. caused some dispersing of soil surface, particularly of silty clay plot.

**1973** (Fig. 2d). The yields from 1973 were small as a whole, those from silty clay mainly negligible in spite of the rather rainy sowing time. However, the poor yields were obviously partly due to the dispersing rains of May 16—19. In consequence, the sprouting of the fourth and fifth sowingsremained very poor. Another factor might have been the high temperature in June; it was almost three degrees higher than normal (Table 1), while the rainfall at the same time was relatively low. These two factors might have reduced the growth of crops.

**1974** (Fig. 2e). The yields from 1974 were almost the best during the entire ten-year period. It is obvious that the 17 mm of rainfall on 8.5. was beneficial to the crops, especially to those of the fourth, fifth and sixth sowings, by improving the moisture conditions in all of the soil types. Actually, there was no difference between the average yields from the first sowing and those from the fifth sowing, although there was an interval of more than three weeks. On the other hand, the heavy rain caused a serious dispersing of silty soil and a subsequent reduction in the yield from the third sowing.

**1975** (Fig. 2f). This year, together with 1971, was the driest during the entire period. This caused the very small yields from the silty clay plot in spite of the rather high rainfall during sowing. Moreover, the rains in June were very scanty, only 11 mm (Table 1). It is worth nothing that the yields of wheat and barley from sandy clay did not decline after the first sowing, thus showing the good capacity of the soil to retain water even under rather dry conditions.

**1976** (Fig. 2g). The yields from 1976 were high on average. The reason is obviously that the rainfall was relatively evenly distributed during the whole growing season (Table 1). Furthermore, the temperature was not high and this partly might have been due to a rather high yield, too. Another factor may be that in the spring the soil was easy to cultivate. The ploughing in autumn 1975 was done under good conditions simplifying preparation of the seed beds in spring.

**1977** (Fig. 2h). The results from 1977 were also rather good. There were no very big differences in the yields as a result of the sowing time, only the average yields from the sixth sowing were smaller than the others.

**1978** (Fig. 2i). May was very dry in 1978, there was only 5 mm of rainfall. In June there was 44 mm of rain (Table 1) but almost all of this was during the later part of the month. The germination and sprouting were thus very much dependent on the capacity of the soil to retain the early spring moisture for the plants. The early sowings were rather early and thus the yields from the earliest sowings were relatively good, but declined with later sowing times. The reason for this is clearly that the dry period lasted from almost the beginning of May up to the middle of

June. Another factor which caused low yields of oats was the large number of aphids.

**1979** (Fig. 2j). In 1979 the sowing was started very late, on May 10. This was due to the heavy rains, which did not permit an earlier start. A consequence of the lateness was that there were only five sowing times. The entire sowing period was very dry, as it had been the preceeding year, too, and the consequence was that the sprouting of the last sowings was very poor.

## Growing time

The growing time was almost unaffected by the time of sowing (Table 3). In Table 3 only three harvesting times are shown, instead of six. The stands of the first and second sowings were harvested on the same day, those from the third and fourth sowings on the same day, and those from the fifth and sixth sowings on the same day. This meant that the growing times for the crops from the second, fourth and the sixth sowings were a little too short, while the crops from the other sowing times were harvested as fully mature. Thus the fully comparable figures in Table 3 are those representing the growing times of the first, third and fifth sowings, and those representing the growing times of the second, fourth and sixth sowings, respectively.

The finding that the growing time was unaffected by the time of sowing very much departs from the common belief that a delay of a certain number of days in sowing in spring time automatically delays the harvesting in autumn by several days, and the delay in autumn will be longer than that in spring. According to the results a delay of a certain number of days in sowing in spring corresponds approximately to a delay of the same length in autumn.

The differences existing between the growing times within the years were large. In a very dry year, like 1973, the growing times were short. That was the case in another dry year, 1975, too. This means that once there is lack of water the crop will mature earlier than under conditions when there is no scarcity of water. In the years when there was no shortage of water and the yield was good, the growing time was long; 1974, 1976 and 1977 are examples of this.

Table 3. The means of the growing times (in days) of the crops according to the sowing times. The shortest and longest growing time in parenthesis. The corresponding year is marked underneath.

| Time of sowing | | Spring wheat | Barley | Oats |
|---|---|---|---|---|
| 1. | | 118,7 | 103,4 | 108,1 |
| | | (105—142) | (94—118) | (95—125) |
| | year | (—73 —74) | (—72 —74) | (—73 —74) |
| 2. | | 114,1 | 98,8 | 103,6 |
| | | (97—134) | (87—110) | (87—118) |
| | year | (—73 —74) | (—73 —74) | (—73 —77) |
| 3. | | 118,9 | 100,0 | 108,6 |
| | | (103—134) | (87—113) | (87—128) |
| | year | (—72, —73 —74, —77) | (—73 —74) | (—73 —77) |
| 4. | | 114,4 | 95,5 | 104,1 |
| | | (98—131) | (82—106) | (82—125) |
| | year | (—73 —77) | (—73 —74) | (—73 —77) |
| 5. | | 116,5 | 102,2 | 111,4 |
| | | (93—131) | (88—115) | (88—130) |
| | year | (—73 —74) | (—73 —71) | (—73 —77) |
| 6. | | 111,4 | 97,0 | 106,9 |
| | | (88—126) | (82—110) | (82—125) |
| | year | (—73 —74) | (—73 —71) | (—73 —77) |

The differences between the shortest and longest growing times were 38 days for wheat, 28 days for barley and 43 days for oats. The fact that such large differences exist even within the same variety clearly shows that grain production in Finland is shadowed by a rather large risk due to the uncertainty of favourable weather conditions. Under certain circumstances, when the growing period happens to be advantageous, it is possible to produce good yields, but there will always be a risk because of the poor predictability of the weather.

## DISCUSSION

Great variability is normal for Finnish crop production (POHJANHEIMO 1961), due to the variability in the weather conditions and to the uncertainty of weather forecasting (MATTSON 1983). Similar results were recently presented by MUKULA (1984) in his study of the yield variations in Finland starting from the beginning of 19th century.

The factor minimizing the growth of crops in Finland is very often the lack of soil water. As ELONEN et al. (1965) have shown it is possible, particularly in dry years, to increase yields by irrigation of silty and silty clay soils. The shortage of precipitation as such is not, in fact, a factor limiting growth; it is more likely that a great part of the precipitation falls during autumn and winter and is thus useless for crops. In this study, during the entire ten-year period under inspection on average of 44,1 % of the rainfall fell during the months from May to September, ranging from 33,4 % (in 1974) to 60,0 % (in 1978).

When the yields were small, as in 1971 and 1973, there was little precipitation. But, on the other hand, high precipitation as such was not a guarantee of a high yield; there must be enough moisture in the soil, particularly during the most intensive growing stage in June. If this is the case, it appears that sowing can be done rather late without a great loss of yield. Although in 1974 the latest sowing was done almost one month after the first one, the differences in yields were small. In some cases the yields from the latest sowings were even bigger than those from the first sowings. Normally, as far as the average figures can be looked on as normal values, the effect of the sowing time was that the best yield was from the second or third sowing but descended thereafter (Fig. 1). However, the results from 1974 also show that under favourable conditions the sowing time can be extended without too serious effects on the yields and that the growing time is not always the biggest limiting factor for good yields.

Soils containing large amount of silt are particularly sensitive to drought. As shown by ELONEN et al. (1967) and AURA (1983) these soils can dry rapidly and deeply in the soil profile under certain weather conditions. The rapid drying is mainly due to the pore size distribution in silty soils, which favours a high rise of water from lower soil layers to the surface by capillary action. These effects can lead to a total loss of the crop.

The silty soils are thus sensitive to drought. Rain will, however, improve their productivity. There was a statistically significant correlation between the yields and the rainfall during the growing season:

| | May | June | July | August |
|---|---|---|---|---|
| Sandy clay | -0,06 | 0,23 | -0,02 | 0,13 |
| Clay loam | 0,08 | 0,44$^{xxx}$ | 0,23$^{xx}$ | 0,09 |
| Silty clay | -0,01 | 0,70$^{xxx}$ | 0,40$^{xxx}$ | 0,23$^{xx}$ |

There seems to be a discrepancy between the results represented in Figures 2a—2j and the

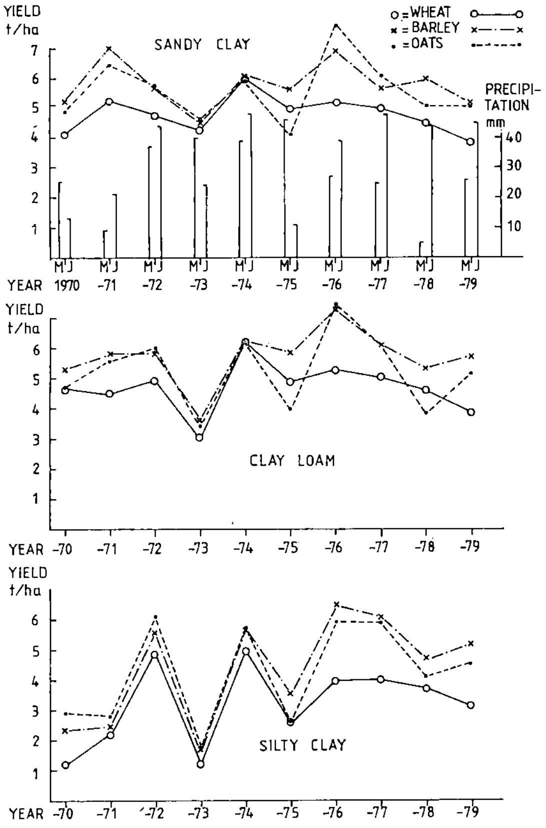


Fig. 3. The maximum yields of the crops on the three soil types presented with the precipitation in May and June.

above correlation coefficients. There was no correlation between the rainfall in May and the yield. On the other hand, the Figures clearly show that a certain amount of rainfall during the sowing time obviously had some effect on the yield. This fact was evident almost every year. The discrepancy is only an apparent one. It was noted that the same rainfall could affect the yields in two ways: by dispersing the seed bed of a previous sowing it caused a decrease in yield, but improved the soil moisture conditions for the next sowings and this caused an increase in the yield. In June the dispersing effects of rains were not so detrimental and therefore the coefficients are clearly positive. It is obvious, however, that also these rains had some dispersing effect but this apparently was of a minor importance.

The soil moisture conditions alone do not determine the yield formation; air temperature clearly also has an effect (EVANS et al. 1980). In 1973 the maximum yields from silty clay plots were smaller than those in 1971 although the rainfall in 1973 was greater. Apparently the mean temperature difference in June in those years had some effect on yield, as in 1974 and 1976.

The fact that very good yields were obtained from silty clay plots during certain years shows that this type of soil can be capable of good crop production. The prevention of the useless evaporation is obviously the fundamental question; they are poor soils if the evaporation cannot be prevented. The high rate of capillary action dries the soil quickly and so the roots are not longer able to penetrate into the hardened soil.

The positive effect of preventing detrimental evaporation from the soil surface was clearly shown by POHJANHEIMO (1965). By covering the soil surface with a 7—8 cm sand layer he was able to increase the yield of spring wheat from 3 600 kg/ha to 7 000 kg/ha. For barley the corresponding increase was from 5 400 kg/ha to 10 300 kg/ha.

The question of soil moisture relationships is closely connected with the soil structural properties of the surface, which are, of course, connected with soil cultivation in the field. It is very probable that by improving soil tillage methods the soil moisture relations can be enhanced even in soils which are now classified as sensitive to drought. In this study, the cultivation procedures were similar in all three soil types. It is therefore not known whether the results would have been different if the cultivation method has been fitted according to the soil type. Future research work should therefore aim to find methods to prevent excess evaporation, particularly from those fields susceptible to water loss.

## REFERENCES

AURA, E. 1983. The compaction of soil in spring by tractor and its effect on soil porosity. J. Sci. Agric. Soc. Finl. 55.

ELONEN, P., NIEMINEN, L. & KARA, O. 1967 a. Sprinkler irrigation on clay soils in Southern Finland. I. Sprinkler irrigation, its technique and effect on soil moisture. J. Sci. Agric. Soc. Finl. 39: 67—77.

— , NIEMINEN, L. & KARA, O. 1967 b. Sprinkler irrigation on clay soils in Southern Finland. II. Effect on the grain yield of spring cereals. J. Sci. Agric. Soc. Finl. 39: 78—89.

EVANS, L. T., WARDLAW, I. F. & FISCHER, R. A. 1980. Wheat. In Crop physiology. p. 374. Ed. EVANS, L. T. London, New York.

KIVISAARI, S. & ELONEN, P. 1974. Irrigation as a method of preventing detrimental late tillering of barley. J. Sci. Agric. Soc. Finl. 43: 194—207.

KONTTURI, M. 1979. The effect of weather on yield and development of spring wheat in Finland. Ann. Agric. Fenn. 18: 263—274.

KRITZ, G. 1983. Såbäddar för vårstråsäd. En stickprovundersökning. Sver. Lantbr. univ. Rapp. 65. 187 p.

KÖYLIJÄRVI, J. 1975. Talvesta kesään. Tuloksia viljakasvien lannoitus-, kylvö- ja rikkakasvien torjuntatutkimuksista. MTTK/Lounais-Suomen koeaseman tiedote 2. 27 p.

LARPES, G. 1979. Aikainen kylvö kevätviljasadon varmentajana. Koetoim. ja käyt. 24.4.1979. p. 14.

LARSSON, S. 1979. Såtidsförsök med korn och havre i Bergslagen. Sver. Lantbr. univ. Rapp. 78. 17 p.

MATTSON, R. 1983. Skördevariationer — orsaker, effekter och motåtgärder. Inledningsanförande vid Sveriges avdelning av NJF:s årsmöte 31.8.1983, Ultuna.

MOGENSEN, V. O. 1980. Drought sensitivity of various growth stages of barley in relation to relative evapotranspiration and water stress Agr. J. 72: 1033—1038.

MUKULA, J. 1984. Viljan keskisatojen kehitys ja satovaihtelut. Suom. Maataloustiet. Seur. Tiedote 5: 4—11.

POHJANHEIMO, O. 1961. Katsaus kevätviljojen satotasoon Kasvinjalostuslaitoksen vertailevissa lajikekokeissa vuosina 1931—60. Valtion Maatal. koetoim. Julk. 192.

— 1965. Kasvien vedentarve ja kevätmuokkaus. Teho 3—4: 129—132.

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## SELOSTUS

# Kylvöajan vaikutus kevätvehnän, ohran ja kauran satoihin kolmella eri maalajilla Tikkurilassa vuosina 1971—1979

SIMO KIVISAARI

Maatalouden tutkimuskeskus

Kasvukauden lyhyyden ja sademäärän epätasaisen jakautumisen vuoksi kylvöajalla on Suomessa tärkeä merkitys kevätviljojen sadolle. Hyvin aikaisin kylvettäessä maa on kylmää ja varsinkin savimaat muokkautuvat huonosti märkyyden takia. Jos kylvöt jäävät kovin myöhäisiksi, alkukesän tavanomainen kuivuus heikentää itämistä ja orastumista. Paras kylvöaika on silloin, kun maa on kuivunut riittävästi ja muokkautuu siten kunnolla, mutta on vielä riittävän kosteata nopeaan ja tasaiseen itämiseen ja orastumiseen.

Tikkurilassa vuosina 1971—1979 järjestetyssä 10-vuotisessa kenttäkokeessa tutkittiin kylvöajan vaikutusta kevätvehnän ohran ja kauran satoihin hietasavella, hiuesavella ja hiesusavella. Kylvöaikoja oli kuusi.

Optimaalinen kylvöaika vaihteli eri vuosina. Vaihtelua lisäsivät ennen kaikkea kevään ja kesän säät, mutta se oli riippuvainen myös maalajista. Keskimääräisesti edullisin kylvöaika oli hieta- ja hiuesavella joko toinen tai kolmas kylvöaika, jotka vastasivat toukokuun päiviä 5. ja 9. Hiesusavella edullisin kylvöaika oli keskimäärin toinen eli 5. toukokuuta.

Erityisesti touko- ja kesäkuun sateet vaikuttivat voimakkaasti satoon. Toukokuun sateet edistivät itämistä ja orastumista, mutta saattoivat myös liettää aikaisempia kylvöjä, ja alentaa siten satoa. Kesäkuun sateet lisäsivät satoa etenkin hiuesavella ($r = 0{,}44^{xxx}$) ja hiesusavella ($r = 0{,}70^{xxx}$). Kasvuajan pituus oli riippumaton kylvöajasta. Kuivina vuosina kasvukausi jäi yleensä lyhyeksi ja sato vähäiseksi. Edullisissa kosteusoloissa kasvuaika yleensä piteni ja lisäsi varsinkin aikaisempien kylvökertojen satoa. Jos kylvö tehtiin myöhään, pidentynytkään kasvuaika ei aina lisännyt satoa. Ero pisimmän ja lyhimmän kasvuajan välillä oli kevätvehnällä keskimäärin 36 vrk, ohralla 25 vrk ja kauralla 38 vrk.

Tulosten perusteella on suositeltavaa pyrkiä niin aikaiseen kylvöön kuin maan muokkautuvuuden perusteella on mahdollista. Erittäin myöhäistä kylvöä ei voida suositella savimaille, mutta ei kovin aikaistakaan. Tosin tietyissä hyvin edullisissa oloissa tällaisistakin kylvöistä saatiin varsin hyviä satoja.

ANNALES AGRUCULTURAE FENNIAE, VOL. 23: 158—170 (1984)

Seria AGROGEOLOGIA ET -CHIMICA N. 129 — Sarja MAA JA LANNOITUS n:o 129

# MICRONUTRIENT CONTENTS OF DIFFERENT PLANT SPECIES GROWN SIDE BY SIDE

TOIVO YLÄRANTA and MIKKO SILLANPÄÄ

YLÄRANTA, T. and SILLANPÄÄ, M. 1984. **Micronutrient contents of different plant species grown side by side.** Ann. Agric. Fenn. 23: 158—170. (Agric. Res. Centre, Inst. Soil Sci., SF-31600 Jokioinen, Finland.)

Different plant species (one variety of each) including root and grain crops, grasses and legumes were grown during two seasons side by side at nine sites in various parts of Finland.

The micronutrient contents of crops varied widely from one crop to another. The least varying micronutrient was Cu, the highest mean content of which was only fourfold compared to the lowest. In the case of other micronutrients the respective figures were: Fe and Zn 7-fold, B 21-fold, Mn 35-fold, and Mo 46-fold.

The highest B contents were found in legumes and in the tops of root crops and the lowest in grain crops with straws containing somewhat more B than grains. Likewise, in the case of Cu the highest contents were measured in legumes. The lowest were found in the underground parts of some root crops and in the straws of the grain crops. Potato tuber, onion bulb and swede root are very low in Fe, Mn, Mo and Zn while pea stalk and sugar beet tops are rich in most of these. In addition, some grasses and clover, especially when cut at an early stage, contain these elements in abundance, Zn often being an exception. Quite a high Zn contents were typical of grains.

Considerable differences also existed between the micronutrient contents of various parts of plants. Among the crops studied the most heterogenous in this respect were the pea and sugar beet.

The results also indicate the complexity involved and difficulties in interpreting the results of plant analyses in estimating the micronutrient status of respective soils.

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Index words: micronutrient content, boron, copper, iron, manganese, molybdenum, zinc, cereals, timothy, red clover, rape, rye grass, pea, onion, turnip, carrot, potato, beet, swede.

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## INTRODUCTION

Estimation of the status of plant available micronutrients of soils in usually based on soil analyses, plant analyses or on a combination of both. These analyses are based on fundamentally different principles and the micronutrient fractions to be analyzed are obtained by different means, i.e. the same fractions do not appear in the two types of analyses. Plant analysis holds a theoretical advantage over soil analysis in that the micronutrient fractions found in plants have indeed been in the soil in forms available to plants while soil analysis is to be considered as an attempt to imitate plants. A more detailed review on the theoretical and practical advantages and limitations of the two types of analyses is presented in FAO Soils Bull. 48, chapters 2.3 and 2.6 (SILLANPÄÄ 1982).

This study attempts to offer further information on the behaviour of various plant species (and parts) with respect to their micronutrient absorption and thus, on interpretation of the results of plant analyses. So far, comprehensive interpretation systems have been developed for only relatively few plant species. Very little is known about the differences between plant varieties and no general agreement has been reached as to which parts of different plants should be analyzed. Further, to meet the condition of comparability, samples to be used for plant analysis must be taken when the plants are at the same physiological age. Analyses of samples collected at different stages of growth are not comparable and may give a misleading estimate of the micronutrient status of soils (YLÄRANTA et al. 1979). This limits the sampling to a very short period, which from a practical point of view, is a serious drawback to the use of plant analysis.

Although the micronutrient contents of different plant species have often been reported (e.g. BERGMANN and NEUBERT 1976) the data, almost without exception, originate from dissimilar soils and growing conditions, consist of divergent varieties and, therefore, are not strictly comparable. In an attempt to eliminate these disruptive factors and to improve the comparability between the various plant species of this study, crops were grown side by side at nine sites and analysed in one laboratory by the same methodology. The results obtained refer to typical Finnish growing conditions.

## MATERIAL AND METHODS

The trials were carried out at nine sites in different parts of Finland (Fig. 1.). The soils consisted of clay soils (sites 2, 3 and 5), a sandy loam (site 1), finesand (sites 4 and 6) and organogenic (sites 7, 8 and 9) soils (Table 1).

The soils were sampled (0—20 cm, 10 subsamples from each site) before implementing the trials. Texture was determined by the pipette method (ELONEN 1971), organic C with a Leco CR-12 carbon determinator (SIPPOLA 1982) and

Table 1. General soil properties and extractable micronutrients of top soils at the experimental sites.

| Site | Particle size distr. (%) <,002 | ,002 —,02 | ,02 —,2 | >,2 mm | Org. C % | pH (CaCl$_2$) | Electr. cond. $\frac{10^{-4}S}{cm}$ | Micronutrients (mg/l) B | Cu | Fe | Mn | Mo | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Häme Res. Station | 15 | 24 | 26 | 35 | 1,7 | 5,3 | ,9 | ,88 | 2,3 | 200 | 63 | ,108 | 1,9 |
| 2. Sata-Häme Res. Sta. | 36 | 48 | 11 | 5 | 3,8 | 5,1 | 2,0 | ,49 | 3,1 | 340 | 77 | ,084 | 3,8 |
| 3. S.W. Finland Res. Sta. | 34 | 19 | 46 | 1 | 1,7 | 4,0 | 1,6 | ,47 | 5,9 | 610 | 11 | ,040 | 1,9 |
| 4. S. Savo Res. Sta. | 4 | 8 | 74 | 14 | 4,4 | 4,8 | 1,5 | ,65 | 2,3 | 370 | 14 | ,016 | 4,2 |
| 5. Inst. of Soil Science | 70 | 21 | 8 | 1 | 4,7 | 4,5 | 1,8 | 1,29 | 6,3 | 1230 | 14 | ,020 | 2,5 |
| 6. Central Finland Res. Sta. | 4 | 9 | 84 | 3 | 1,5 | 4,8 | ,9 | ,48 | 1,2 | 170 | 82 | ,096 | 5,9 |
| 7. Kainuu Res. Sta. | — | — | — | — | 47 | 4,1 | 1,3 | 1,49 | 12,0 | 1410 | 8 | ,002 | 2,0 |
| 8. N. Savo Res. Sta. | 26 | 42 | 26 | 6 | 16 | 4,6 | 4,2 | ,21 | 5,3 | 2130 | 34 | ,074 | ,8 |
| 9. S. Ostrobothnia Res. Sta. | 28 | 44 | 28 | — | 19 | 4,9 | 2,3 | 1,59 | 2,6 | 1240 | 93 | ,030 | 24,6 |
| Mean |  |  |  |  |  | 4,7 | 1,8 | ,84 | 4,6 | 856 | 44 | ,052 | 5,3 |
| ± s |  |  |  |  |  | 0,4 | 1,0 | ,50 | 3,3 | 678 | 35 | ,039 | 7,4 |

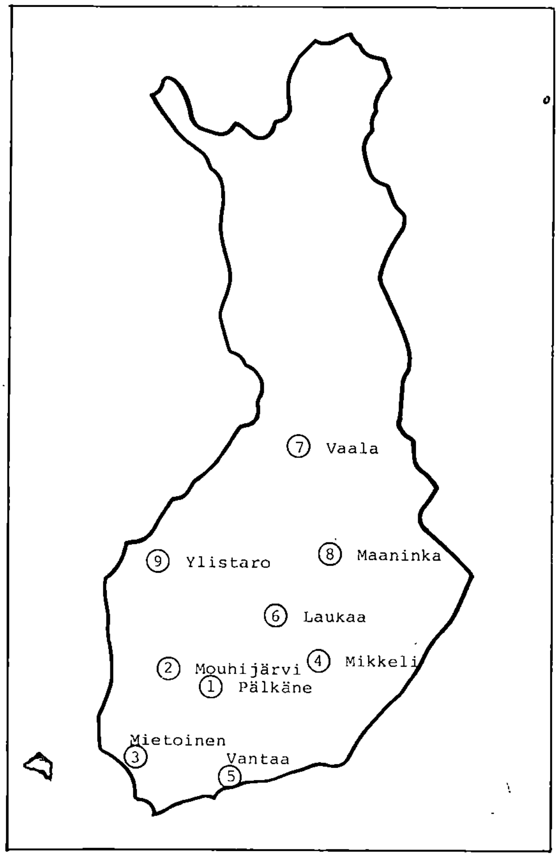

Fig. 1. Locations on experimental sites. 1 = Häme Res. Station, 2 = Sata-Häme Res. Sta., 3 = S. W. Finland Res. Sta., 4 = S. Savo Res. Sta., 5 = Inst. of Soil Science, 6 = Central Finland Res. Sta., 7 = Kainuu Res. Sta., 8 = N. Savo Res. Sta., 9 = S. Ostrobothnia Res. Sta.

pH ($CaCl_2$) from 0,01 M $CaCl_2$ suspension (v/v 1: 2,5) two hours after stirring. The micronutrients Cu, Fe, Mn, Mo and Zn were extracted from the soils with acid ammonium acetate-EDTA (0,5 M $CH_3COONH_4$, 0,5 M $CH_3COOH$, 0,02 M $Na_2$ EDTA, pH 4,65; LAKANEN and ERVIÖ 1971) and hot water soluble B by a modified BERGER — TRUOG (1944) method (SIPPOLA and ERVIÖ 1977).

The trials at each site consisted of the following crops with 5 x 5 m rows and 12,5 cm spacing: Spring wheat (variety Apu); Winter wheat (v.Vakka); Oats (v. Tiitus); Barley (v. Otra); Rye (v. Aitta); Timothy (v. Tammisto); Red clover (v. Venla); Turnip rape (v. oleifera DC., v. Span); Italian rye grass (v. Barmultra tetila); Pea (v. Ville). The following crops had a 1 x 5 m row with 50 cm spacing: Onion (v. aggregatum, v. Rijnsburger); Turnip (v. Petroski); Carrot (v. Nantes 20 Notabene); Potato (v. Pito); Red beet (v. rubra, v. Rubia); Sugar beet (v. saccharifera Lge, v. AaBeCe); Swede (v. napobrassica, v. Mustiala).

Winter crops were sown in 1976 and summer crops in 1977. An attempt was made to carry out the trials for two years, 1977—78, at all nine sites. Some of the crops, however, were succesfully grown at seven or eight sites only. To guarantee satisfactory growth the experimental fields were fertilized before sowing. The compound fertilizer (350 kg/ha, 15-15-15) was placed in the rooting zone, except in case of grass crops which were fertilized after each cutting by the broadcast method. Each yield received fertilizer nutrients as follows:

| | | | | | |
|---|---|---|---|---|---|
| N | 53 | kg/ha | S | 8,8 | kg/ha |
| P | 23 | ,, | Mg | 2,5 | ,, |
| K | 44 | ,, | Cl | 42,0 | ,, |
| Ca | 33 | ,, | B | 0,11 | ,, |

Firstly, the nutrient contents of the edible plant parts were analysed. In case of grain crops, however, the straw, as well as the stalks of pea and turnip rape and both the aboveground and underground parts of swede and sugar beet were analysed separately. In the case of grasses one half of the plots were cut for silage before flowering, the other half was allowed to mature further then harvested as dry hay. Red clover was sampled at the stage of full flowering. The fresh growth yields of timothy and red clover were also sampled.

Three samples, about 100 g DM, of each crop were analysed separately. There were no problems in sampling of grasses or grain crops. In the case of root crops, e.g. carrot, the following procedures were adopted: seven roots of medium size were washed with tap water, brushed and then rinsed with deionized water. The roots were cleaved into four equal parts, of which one from each root was cut into pieces not exceeding 1 cm$^3$, and dried at 60 °C. The ashing at 450 °C, preparation and dilution of the ash is described by SILLANPÄÄ (1982). The Cu, Fe, Mn and Zn contents of plants were measured with an atomic absorption spectrophotometer, B by a modified azomethine-H method (BASSON et al. 1969, JOHN et al. 1975, SIPPOLA and ERVIÖ 1977) and Mo by the zinc dithiol method (STANTON and HARDWICK 1967).

## RESULTS AND DISCUSSION

**Boron.** The hot water soluble B contents of the soils at the nine sites of this study average 0,84±0,50 mg/l (Table 1) which is somewhat higher than the Finnish average (0,55±0,28 mg/l) presented in a global micronutrient study (SILLANPÄÄ 1982). It also slightly exceeds the world average (0,73±0,75 mg/l). This is mainly due to the relatively high B status of soils at Sites 9 and 7 (South Ostrobothnia and Kainuu Research Stations). At other sites the soil B contents correspond those of typical Finnish soils except at Site 8 (North Savo Research Station) where a very low soil B value (0,21 mg/l) was recorded. The relatively wide variation of soil B values is naturally reflected in the plant B contents also.

In general, the content of hot water soluble B of Finnish soils has been increasing during recent years. According to soil testing statistics (KÄHÄRI 1983) their average B content has increased from 0,484 mg/l in 1976—80 (124952 samples) to 0,588 in 1981—82 (60447 samples). This is understandable on the basis of the fact that almost all Finnish compound fertilizers contain 0,03—0,2 per cent boron.

The B content of monocotyledon plants is generally lower than that of dicotyledons. Thus the lowest B contents (1—4 ppm in DM) were measured from grain crops; straws having a somewhat higher B content than grains (Fig. 2).

Potatoes (~6 ppm) and grasses (5—11 ppm) were also relatively low in B. Leguminous crops and root crops (especially tops) had the highest B contents. A considerable difference between the two parts of the pea, the stalk (29,4±10,2 ppm) and the seed (7,5±1,0 ppm), is notable. The difference between the highest and lowest mean was 21-fold.

One of the very rare studies where the micronutrient contents of plants grown on the same soil are compared is that of BERTRAND and WAAL (1936) concerning boron. Their results (ppm in DM):

| | | | | | |
|---|---|---|---|---|---|
| Barley | 2,3 | Onion | 4,3 | Carrot | 25,0 |
| Rye | 3,1 | Pea | 21,7 | Turnip | 49,2 |
| Wheat | 3,3 | | | | |

are generally in agreement with those of the present study although they present a B content which is higher for the turnip and lower for the onion than the respective figures in this study.

Obviously, the present B data represent quite a satisfactory B status although some of the figures are slightly on the low side. The lowest B values of different plants were almost always measured from Site 8 material and often approach the critical deficiency level. For example, BRANDENBURG and KORONOWSKI (1969) give B contents of 25—40 ppm for tops and 15 ppm for roots of healthy sugar beets. The corresponding figures for B-deficient plants are 13—20 and 13 ppm, and those from Site 8 20 and 13 ppm, respectively. In the case of turnip

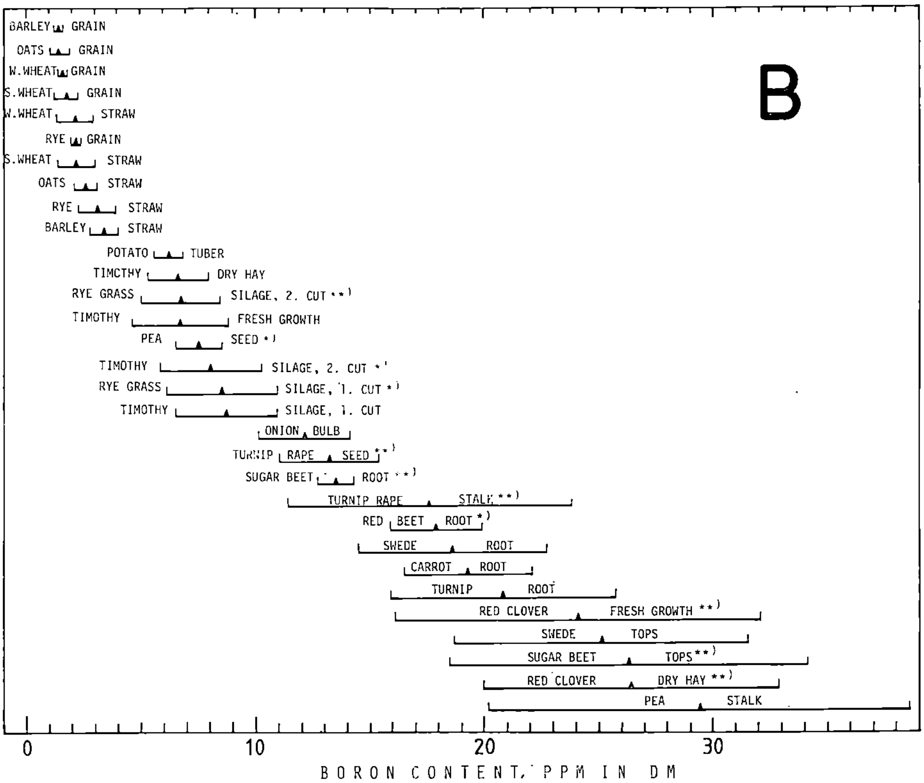

Fig. 2—7. Two-year averages ($\bar{x} \pm s$) of micronutrient contents of different parts of 17 crops grown side by side at nine sites. Crops grown succesfully at eight sites $^{x)}$ or at seven sites $^{xx)}$ only are indicated in Fig. 2.

roots the B contents of healthy, B-deficient and Site 8 plants are 18—22, 8—15 and 16 ppm, respectively.

**Copper.** The average acid ammonium acetate — EDTA (AAAc—EDTA) extractable copper of the soils of this study (4,6 ± 3,3 mg/l, Table 1) corresponds well with the respective data for Finland (4,31 ± 2,68 mg/l) presented in a global study (SILLANPÄÄ 1982) and is somewhat lower than the average for the whole of the international material (6,00 ± 7,05 mg/l). The relatively wide variation of soil Cu in this study is mainly due to two sites: the lowest figure (1,2 mg/l) from Site 6 (Central Finland Res. Sta.) and the highest (12,0 mg/l) from Site 7 (Kainuu Res. Sta.). However, compared to the international material (min. 0,1 and max. 99,9) the variation range is narrow. None of the present soil Cu values indicates Cu deficiency although that of Site 6 is close to the critical range, which for the extraction method used is considered to be 0,8—1,0 mg/l (SILLANPÄÄ 1982).

The Cu content of various plant species is subject to less variation than that of most other elements (Fig. 3). The difference between the lowest and the highest mean, swede root and fresh growth of red clover, is only about fourfold. In addition, the internal variation within different plant species and parts is quite narrow; the standard deviation seldom exceeding one third of the mean.

The highest Cu contents were found in leguminous crops, pea and red clover, usually between 6 and 17 ppm. Grasses had somewhat

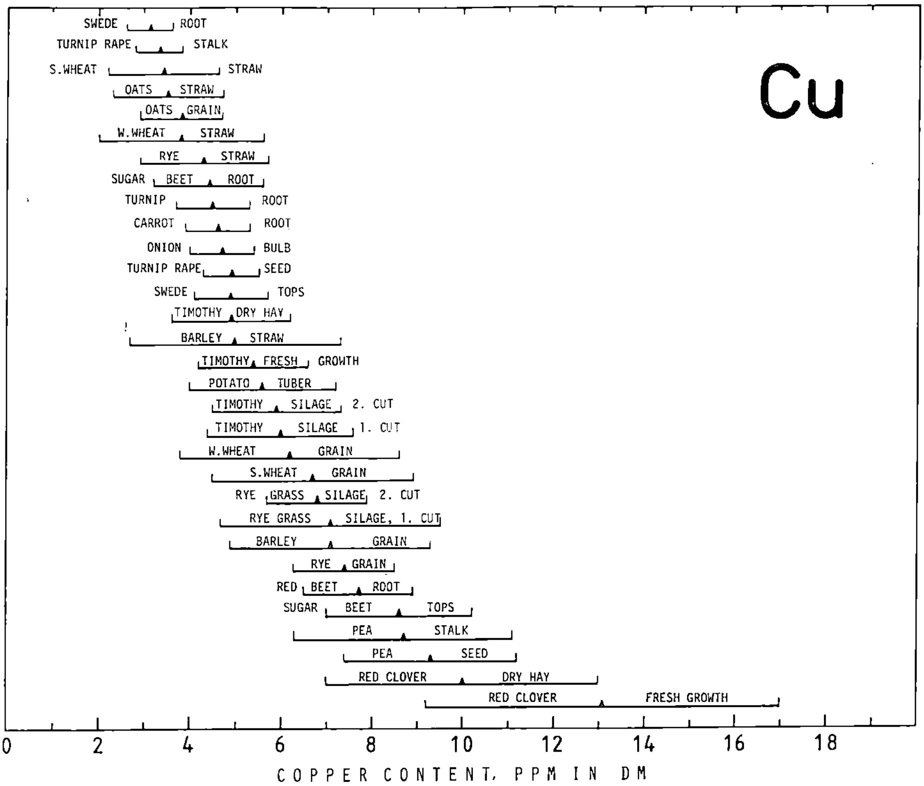

Fig. 3.

lower Cu contents, varying from 4 to 9 ppm. Most grains were at this Cu level too, but straws contained 2—3 ppm less Cu than grains. In the case of oats, both the grain and the straw, were at a low, 2—5 ppm Cu level. Root crops are rather heterogeneous with respect to their Cu content. Of roots swede was the poorest in Cu (about 3 ppm) and red beet the richest (about 8 ppm). The tops of swede and sugar beet contained 1,6—2,0 times as much Cu as their roots.

In general, the plant Cu data of this study may be slightly on the low side. For example, BEESON et al. (1947) found the Cu content of 17 grass species ranged from 4,5 to 21 ppm. The average Cu contents of timothy were reported by ZACHERL et al. (1965), SCHILLER et al. (1967) and LAKANEN (1969) as 6,9, 6,4 and 6,3 ppm, respectively. In the last mentioned study the range was from 1,9 to 12,5 ppm. Somewhat lower Cu contents of hay ranging from 0,8 to 10,4 (aver. 3,8) ppm have been reported from Poland by GLIŃSKI and KRUPIŃSKI (1969).

**Iron.** The AAAc—EDTA extractable soil Fe in the nine sites of this study, 856±678 mg/l (Table 1) exceeds that of the Finnish soils in the global stydy, 569±367 mg/l (SILLANPÄÄ 1982). Even the latter was higher than that of any other of the thirty countries involved in the study. The world average was 166±157 mg/l. In addition, the AAAc—EDTA extractable Fe content of 2015 Finnish soils (677±656 mg/l) reported by SIPPOLA and TARES (1978) was lower than that of the present study.

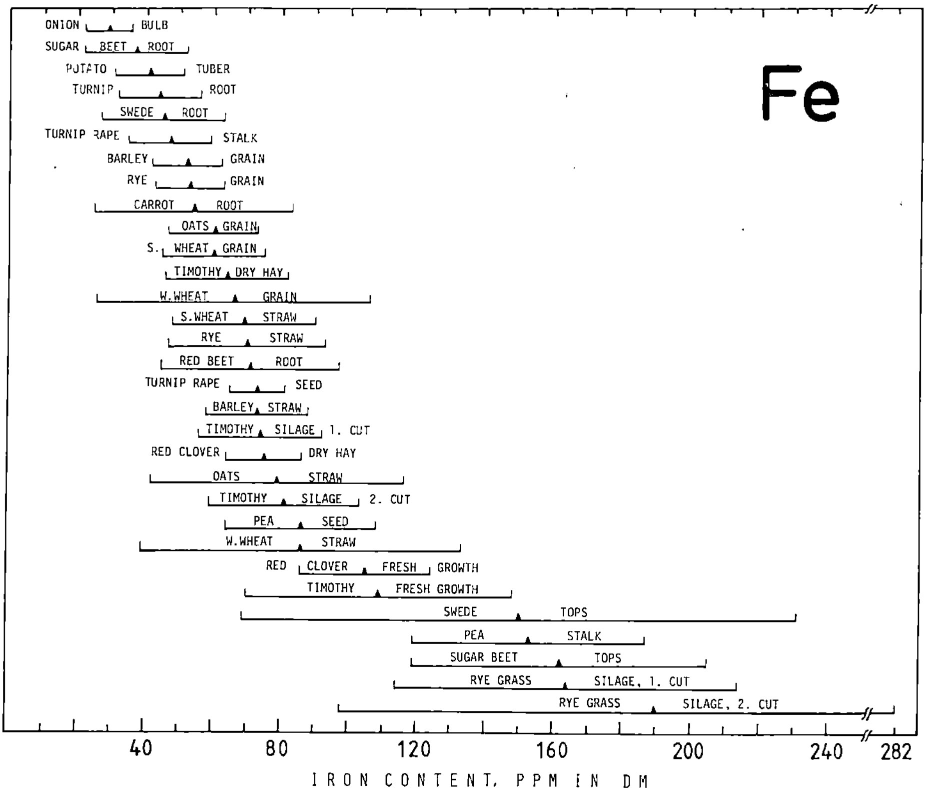

Fig. 4.

The lowest Fe contents were found in onion bulb, potato tuber and in the underground parts of some root crops, averaging generally 30 to 55 ppm, with the exception of red beet roots (Fig. 4). Contrary to their low root Fe contents, the tops of swede and sugar beet are rich in Fe exceeding three to four times the root Fe contents. Relatively low Fe contents were also measured from grain crops, especially from grains which contained from 52 (barley and rye) to 66 ppm (winter wheat) iron on the average. The respective mean Fe contents of straws were about 20 ppm higher varying from 69 to 86 ppm.

The Fe content of grasses varies widely depending on the species and on the physiological age of the plant. In general, rye grass contains twice as much Fe as timothy and more than any other crop studied here. Further, plants analysed at a young physiological age (fresh growth, silage) contain more Fe on dry basis than the mature crop (hay). The decrease of Fe with increasing age may be quite substantial. For example, in an experiment with wheat (YLÄRANTA et al. 1979) the Fe content decreased from 120 ppm level in early June to 40 ppm level in August.

Leguminous crops, red clover and pea, are quite rich in Fe. The pea stalk contains almost twice as much Fe as the seed. This may be partly due to contamination by soil, which in the case of Fe is more difficult to control than that of other micronutrients (see SILLANPÄÄ 1982). This concerns especially those parts of the plant which are exposed to contamination by soil dust raised by wind, the spattering of rain or other plant-soil contacts.

Fe contents in Finnish timothy varying more than in this study, i.e. from 25 to 262 ppm

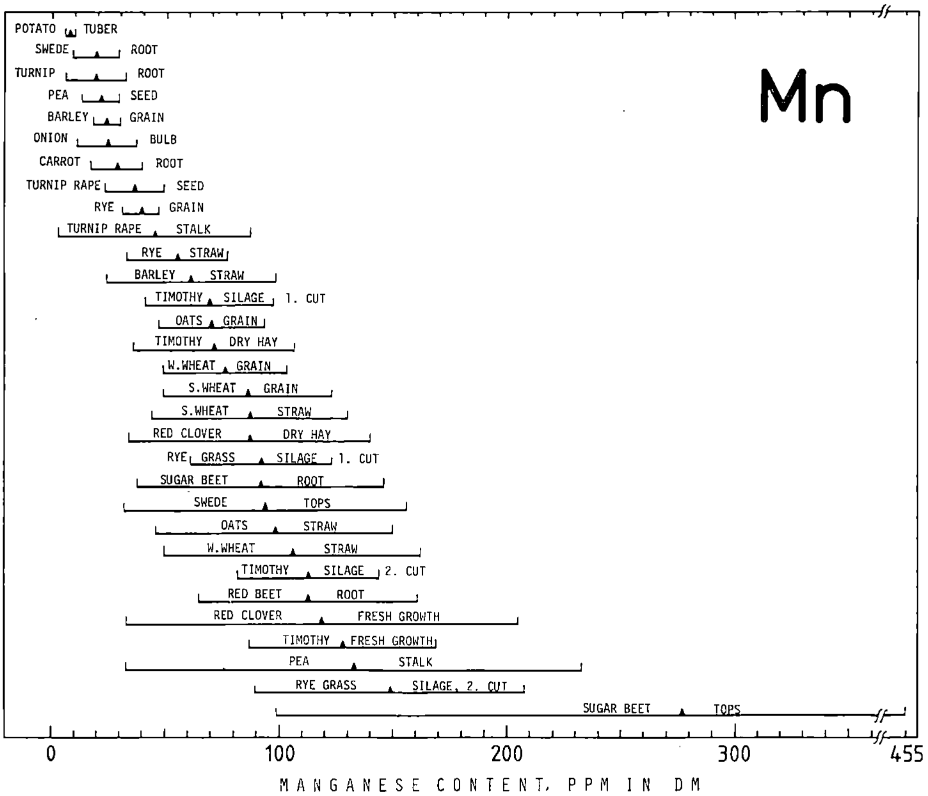

Fig. 5.

(aver. 81 ppm), were reported by LAKANEN (1969). Both higher and lower Fe contents in timothy and other crops have been reported elsewhere (e.g. FLEMING 1963, RUSSEL and DUNCAN 1956, KÄHÄRI and NISSINEN 1978).

**Manganese.** As shown by SILLANPÄÄ (1982) the AAAc—EDTA extraction method as such is a very poor indicator of the Mn status of soils. This is true especially on the acid soil range, pH($CaCl_2$) <7, where it gives Mn values, which are much too low. When combined with pH correction, however, it is a useful method. The AAAc—EDTA extractable soil Mn values presented in Table 1 are raised substantially by pH correction, i.e. from 44±35 to 219±112 mg/l. The latter values are somewhat on the low side in the international comparison.

The lowest plant Mn contents were measured in potato tuber, <10 ppm on a dry basis (Fig. 5). Moreover, the underground parts of some root crops (swede, turnip and carrot) were poor in Mn, mostly 10—40 ppm, while others (sugar beet and red beet) had Mn contents more than three times as high. In root crops Mn seems to be concentrated mainly in the tops, as the high contents of swede tops and especially those of sugar beet tops indicate. With respect to Mn, various grain crops also behave differently. The average Mn contents of grain vary from 24 ppm (barley) up to around 80 ppm (wheats). A similar difference can be noted in the case of straws, even though at a somewhat higher Mn level.

In the pea, Mn seems to be concentrated in the stalk (133±100 ppm) while the seed contains little it (21±8 ppm). Considerable variations in the Mn contents of pasture species exist both between the species and between different cuttings. In general, rye grass contains more Mn

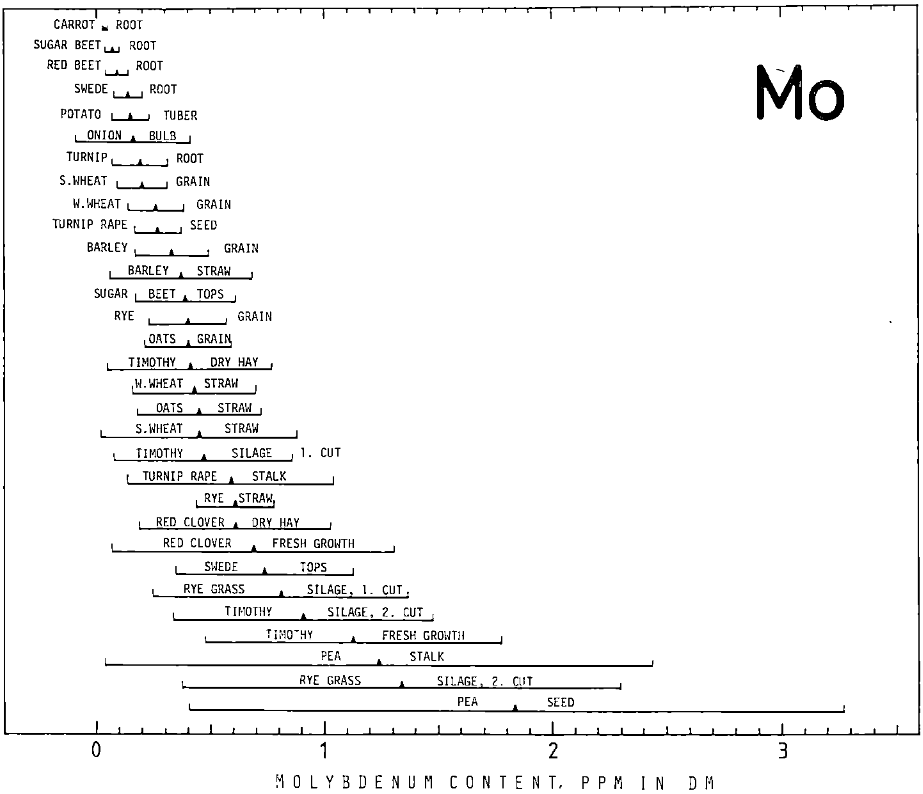

Fig. 6.

than the respective samplings of timothy, and late cuttings more than early cuttings. Fresh growths of red clover and timothy are much richer in Mn than the respective species as dry hay.

Compared to most other micronutrients the variation of Mn contents between the plant species (35-fold difference between the lowest and highest mean) is wide. It is apparent that the internal variation within each plant species is mainly due to variation in the soil pH of different sites. Thus, the highest Mn contents of almost every crop were measured from samples originating from Sites 3 and 7 (S.W. Finland and Kainuu Res. Stations) with the most acid experimental soils ($pH(CaCl_2)$ 4,0 and 4,1, respectively). The lowest Mn values usually came from Sites 1 and 2 (Häme and Sata-Häme Res. Stations) with the least acid soils (pH 5,3 and 5,1, respectively). On the whole, the internal variations in Mn contents (or in pH) cannot be considered wide. For example, in the global study by SILLANPÄÄ (1982) the wheats grown on acid soils ($pH(CaCl_2) \sim 4$) on the average contained about ten times more Mn than wheats grown on alkaline soils ($pH \sim 8$).

In general, based on the figures given in the literature, the Mn contents of plants in this study do not indicate Mn deficiency nor toxicity.

**Molybdenum.** AAAc—EDTA extraction has seldom been used for determining plant available soil Mo. However, comparable results from larger materials have been published by SILLANPÄÄ et al. (1975) and SIPPOLA and TARES (1978). Both of these studies concern Finnish soils and, on the average, their Mo levels, 0,052 and 0,047 mg/l, respectively, correspond well to those of the present study (0,052 ± 0,039 mg/l, Table 1).

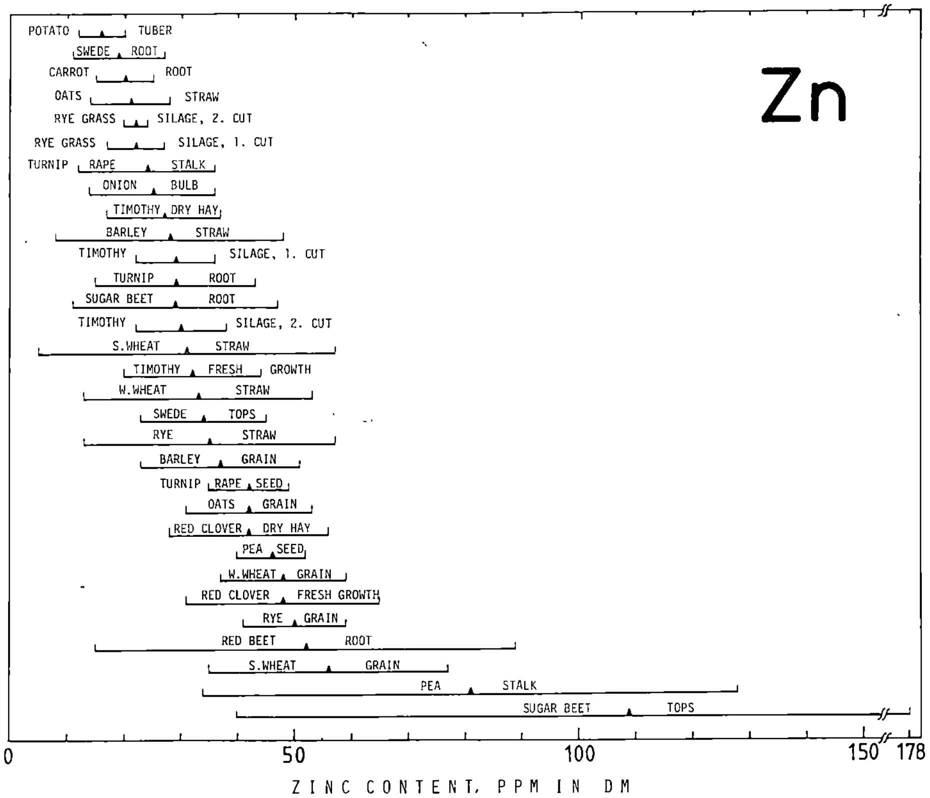

Fig. 7.

The lowest Mo contents were found in the underground parts of root crops, all averaging less than 0,2 ppm (Fig. 6). Grain crops are also relatively low in Mo; the mean values for grains lying between 0,2 and 0,4 ppm, and straws between 0,4 and 0,6 ppm. The means for pasture species varied from 0,41 ppm of timothy (dry hay) to 1,34 ppm of rye grass (silage, 2. cut). The very highest Mo contents were found in pea, the stalk containing 1,24 ± 1,20 ppm and seed 1,84 ± 1,43 ppm.

The difference between the lowest and the highest mean Mo content of plants, carrot root and pea seed, was 46-fold, which is the widest among the six micronutrients of this study. Wide variations of Mo contents also exist within the plant species studied. As in the case on Mn these variations are largely due to variations in soil pH which is a strong regulator of Mo availability. Its effect, however, is opposite to that of Mn availability. Thus, the lowest Mo contents of the 31 different plants and plant parts were, with only two exceptions, found in samples which originated from Site 7 (Kainuu Res. Sta.) where in addition to low soil Mo the soil was extremely acid (Table 1). In addition, with two exceptions the Kainuu plant Mo contents were below 0,1 ppm. For the above reasons the next lowest plant Mo values came from Sites 3 and 5. In the global study (SILLANPÄÄ 1982) the effect of pH was very clear. The Mo content of wheats grown on alkaline soils, $pH(CaCl_2) \sim 8$, was tenfold compared to those grown on acid soils ($pH \sim 4$).

The general level of Mo in the plants of this study seems to be quite similar to those reported from other Finnish materials. For example, in a study by PAASIKALLIO (1978) the mean Mo content of about 2000 timothy plants collected before flowering was 0,47±0,58 ppm, which is equal to that of the 1st cut silage timothy in this study, lower than those of the 2nd cut fresh growth but higher than that of dry hay. The figures for timothy (0,62±0,63 ppm) given by LAKANEN (1969) are of the same magnitude. In an international comparison (SILLANPÄÄ 1982) the Finnish materials (both original and pot growth wheats) were slightly, but clearly on the low-Mo side. Against this background it seems likely that the experimental soil at Kainuu (and possibly at S.W. Finland Res. Sta.) was not able to supply plants sufficiently with Mo. At other sites Mo deficiency seems unlikely.

**Zinc.** Excluding the exceptionally high Zn value from Site 9 (24,6 mg/l, S. Ostrobothnia Res. Sta.) the AAAc—EDTA extractable soil Zn values given in Table 1 correspond well with the respective Finnish Zn data in the global study (SILLANPÄÄ 1982). In the latter material the soil Zn data from Finlad are slightly on the high side in the international comparison.

The lowest mean Zn contents among the plants was measured in potato tuber (16±4 ppm, Fig. 7). The underground parts of most root crops were also low in Zn, the mean contents varying from 19 to 29. Red beet root, however, was an exception having a Zn content of 52±37 ppm. Only slightly higher Zn contents than that of root crops were found in the straws of the grain crops averaging 21—35 ppm. In grain the respective figures were higher varying from 37 to 56 ppm. Of the grasses timothy contained more Zn than rye grass but both are relatively poor in Zn. Legumes, red clover and pea (especially the stalk) are quite rich in Zn. However, the highest mean Zn content (109±69 ppm), seven times as high as the lowest (potato), was measured in sugar beet tops.

As could be expected on the basis of the soil data (Table 1) the plants grown at Site 9 had higher Zn contents (with only two exceptions) than plants grown at any other site. In general, the Zn contents of plants in this study seem to be at the normal Finnish level. For example, the Zn contents of timothy reported by LAKANEN (1969) and KÄHÄRI and NISSINEN (1978) were of the very same magnitude as those in this study, i.e. 30,8±13,2 ppm and 32,0±8,5 ppm, respectively. In an international comparison (SILLANPÄÄ 1982) the average Zn level of Finnish wheats sampled at the mid-tillering stage (27,0±5,6 ppm) was almost equal to the world average (27,4±11,3).

**General remarks.** The data on all six micronutrients demonstrate clear dissimilarities in the ability of different plant species to absorb micronutrients from the same soils under equal conditions. Although some species seem to absorb generally more micronutrients than others, their ability to absorb these applies usually to certain micronutrient(s) only, and seldom to all of the six. Further, the differences in the micronutrient contents of different parts of the plants as well as the variation in the content with the physiological age of the plant are additional factors complicating the interpretation of the results of plant analyses, and this, preventing their large scale use in estimating the micronutrient status of soils.

It must be realized that the results presented here refer to very typical Finnish growing conditions. If the plants had been grown on strongly alkaline soils, for example, the relationships between micronutrient contents would be different. For example, in a global comparison study (SILLANPÄÄ 1982) the average Mn content of wheats grown on soils with pH($CaCl_2$) about 4 exceeded those grown on alkaline soils (pH>8) by a factor of approximately ten. Respectively, the Mo contents of wheats grown on alkaline soils were over tenfold compared to those grown on acid soils.

# REFERENCES

BASSON, W. D., BÖHMER, R. G. & STANTON, D. A. 1969. An automated procedure for the determination of boron in plant tissue. Analyst 94: 1135—1141.

BEESON, K. C., GRAY, L. & ADAM, M. B. 1947. The absorption of mineral elements by forage plants. I. The phosphorus, cobalt, manganese and copper of some common grasses. J. Amer. Soc. Agron. 39: 356—362.

BERGER, K. C. & TRUOG, E. 1944. Boron tests and determination for soils and plants. Soil Sci. 57: 25—36.

BERGMANN, W. & NEUBERT, P. 1976. Pflanzendiagnose und Pflanzenanalyse. Zur Ermittlung von Ernährungsstörungen und des Ernährungszustandes des Kulturpflanzen. 711 p. Jena.

BERTRAND, G. & WAAL, H. L. de 1936. Sur la teneur comparative en bore des plantes cultivées sur le même sol. C. R. Acad. Sci. Paris 202: 605—609.

BRANDENBURG, E. & KORONOWSKI, P. 1969. Die nichtparasitären Krankheiten, VIII. Bor. Handbuch der Pflanzenkrankheiten. Verlag Paul Parey, Berlin. 2. Teil: 132—170.

ELONEN, P. 1971. Particle-size analysis of soil. Acta Agr. Fenn. 122: 1—122.

FLEMING, G. A. 1963. Distribution of major and trace elements in some common pasture species. J. Sci. Fd. Agric. 14: 203—208.

GLIŃSKI, J. & KRUPIŃSKI, A. 1969. (The occurrence of trace elements Cu, Co, Ni, V, Sr and Ba in the soils and hay in the northern part of region of the Wieprz-Krzna canal.) Annls. Univ. Mariae Curie Sklodowska (E) 24: 67—78. (In Polish).

JOHN, M. K., CHUAH, H. H. & NEUFELD, J. H. 1975. Application of improved azomethine-H method to determination of boron in soils and plants. Anal. Lett. 8: 559—568.

KÄHÄRI, J. 1983. Suomen peltojen viljavuuden kehittyminen vuosina 1981 ja 1982. Viljavuuspalvelu Oy 1983. 8 p.

— & NISSINEN, H. 1978. The mineral element contents of timothy (*Phleum pratense* L.) in Finland. I. Acta Agric. Scand., Suppl. 20: 26—39.

LAKANEN, E. 1969. Mineral composition of Finnish timothy. Ann. Agric. Fenn. 8: 20—29.

— & ERVIÖ, R. 1971. A comparison of eight extractans for the determination of plant available micronutrients in soils. Acta Agr. Fenn. 123: 223—232.

PAASIKALLIO, A. 1978. The mineral element contents of timothy (*Phleum pratense* L.) in Finland. II. Acta Agric. Scand., Suppl. 20: 40—52.

RUSSEL, F. C. and DUNCAN, D. L. 1956. Minerals in pasture: Deficiencies and excesses in relation to animal health. Commonw. Bur. Anim. Nutr. Techn. Comm. 15: 1—170.

SCHILLER, H., GUSENLEITNER, J., LENGAUER, E., HOFER, B., VOAK, H. & MEISSNER, H. 1967. Fruchtbarkeitstörungen bei Rindern im Zusammenhang mit Düngung, Flora und Mineralstoffgehalt des Wiesenfutters. Landwirtsch. -chem. Bundesversuchsanst. Linz/D.7: 1—136.

SILLANPÄÄ, M. 1982. Micronutrients and the nutrient status of soils: a global study. FAO Soils Bull. 48. 444 p.

— , LAKANEN, E., TARES, T. & VIRRI, K. 1975. Hivenaineiden uutto EDTA:lla tehostetulla happamalla ammoniumasetaatilla suomalaisista maista. Kehittyvä Maatalous 21: 3—13.

SIPPOLA, J. 1982. A comparison between a dry-combustion method and a rapid wet-combustion method for determining soil organic carbon. Ann Agr. Fenn. 21: 146—148.

— & ERVIÖ, R. 1977. Determination of boron in soils and plants by the azomethine-H method. Finn. Chem. Lett. 1977: 138—140.

— & TARES, T. 1978. The soluble content of mineral elements in cultivated Finnish soils. Acta Agric. Scand., Suppl. 20: 11—25.

STANTON, R. E. & HARDWICK, A. J. 1967. The colorimetric determination of molybdenum in soils and sediments by zinc dithiol. Analyst 92: 387—390.

YLÄRANTA, T., JANSSON, H. & SIPPOLA, J. 1979. Seasonal variations in micronutrient contents of wheat. Ann. Agric. Fenn. 18: 218—224.

ZACHERL, M. K., WEISER, M. & ONDERSCHEKA, K. 1965. Über den Mineralstoffgehalt des Heus. Wiener Tierärztl. Mon. Schr. 52: 957—967.

# SELOSTUS

## Viljelykasvien hivenravinnepitoisuuksien vertailu

TOIVO YLÄRANTA ja MIKKO SILLANPÄÄ

Maatalouden tutkimuskeskus

Tutkimuksessa pyrittiin saamaan vertailukelpoista tietoa eri viljelykasvien ja niiden osien hivenravinnepitoisuuksista sekä kasvianalyysitulosten käytöstä maan hivenravinnetilanteen arvioinnissa.

Hivenravinnepitoisuuksien vertaamiseksi kasvatettiin eri kasvilajeja rinnakkain kahden kasvukauden ajan yhdeksällä, eri puolilla Suomea sijaitsevalla koepaikalla. Kokeissa olivat mukana lähes kaikki tärkeimmät viljelykasvilajimme. Koemaat, joihin kuului sekä hienoja ja karkeita kivennäismaita että eloperäisiä maita, olivat melko happamia. Niiden pH($CaCl_2$) vaihteli 4,1:stä 5,3:een. Koemaiden uuttuvien hivenravinteiden pitoisuudet vastasivat muutamin poikkeuksin suomalaisten viljelymaiden keskimääräistä tasoa. Kuuden hivenravinteen (boori, kupari, rauta, mangaani, molybdeeni ja sinkki) pitoisuudet määritettiin korjuuasteen saavuttaneista kasveista.

Kasvilajien hivenravinnepitoisuudet vaihtelivat suuresti. Vähiten vaihtelua todettiin kuparipitoisuuksissa, joissa vähiten ja eniten kuparia sisältäneiden kasvilajien välinen ero oli vain nelinkertainen. Muiden hivenravinteiden pitoisuuksissa vastaavat erot olivat: rauta ja sinkki 7-kertainen, boori 21-kertainen, mangaani 35-kertainen ja molybdeeni 46-kertainen.

Korkeimmat booripitoisuudet mitattiin palkokasveista ja juurikasvien naateista ja alhaisimmat viljoista. Viljojen oljet sisälsivät jonkin verran enemmän booria kuin jyvät. Palkokasveissa todettiin myös korkeimmat kuparipitoisuudet. Vähiten kuparia sisälsivät eräiden juurikasvien maanalaiset osat ja viljojen oljet.

Perunan mukulan, sipulin ja lantun juuren rauta-, mangaani-, molybdeeni- ja sinkkipitoisuudet olivat erittäin alhaiset, kun taas herneen varret ja sokerijuurikkaan naatit sisälsivät runsaasti useimpia näistä neljästä hivenaineesta. Myös eräissä nurmiheinissä ja puna-apilassa oli runsaasti rautaa, mangaania ja molybdeeniä varsinkin kasvien ollessa aikaisella kehitysasteella. Korkeat sinkkipitoisuudet olivat tyypillisiä viljojen jyville.

Myös eri kasvinosien hivenravinnepitoisuuksissa oli huomattavan suuria eroja, etenkin herneessä ja sokerijuurikkaassa. Herneen varret sisälsivät neljä kertaa niin paljon booria ja kuusi kertaa niin paljon mangaania kuin herneen siemenet. Sokerijuurikkaan naattien rauta-, sinkki- ja molybdeenipitoisuudet olivat neljä-kuusikertaisia juuren pitoisuuksiin verrattuna.

Tulokset vahvistivat käsitystä siitä, että kasvianalyysien tuloksiin vaikuttavat hyvin monet eri tekijät. Samalla tuli korostuneesti esille, miten vaikeaa on tulkita maan hivenravinnetilannetta pelkästään kasvianalyysien tulosten perusteella.

ANNALES AGRICULTURAE FENNIAE, VOL. 23: 171—175 (1984)

Seria ANIMALIA NOCENTIA N. 117 — Sarja TUHOELÄIMET n:o 117

Research note

# EFFECTIVENESS OF MECHANICAL OVIPOSITION BARRIERS AGAINST THE CABBAGE ROOT FLY, *DELIA RADICUM,* IN THE LABORATORY

ILKKA HAVUKKALA, MARTTI MARKKULA and MARJA PIRILÄ

HAVUKKALA, I., MARKKULA, M. and PIRILÄ, M. 1984. **Effectiveness of mechanical oviposition barriers against the cabbage root fly, *Delia radicum,* in the laboratory.** Ann. Agric. Fenn. 23: 171—175. (Agric. Res. Centre, Inst. Pest Inv., SF-31600 Jokioinen, Finland.)

The effect of mechanical barriers around the stems of cabbage and radish on oviposition and larval penetration by the cabbage root fly, *Delia radicum,* was studied in the laboratory. Foam-rubber collars 3 cm thick, *Sphagnum* moss, and wood ash sprinkled around the plant stem were tested. Only the collar reduced oviposition significantly. Ash on radish increased the number of eggs laid into the leaf nodes. Larval penetration was not hindered by moss, but dry foam-rubber collars and ash reduced the number of larvae reaching host plant roots at a depth of 3 cm in the soil. Collars displaced oviposition site laterally from the plant stem. Collars and ash seem suitable for the control of the cabbage root fly on small cabbage plots in home gardens.

Index words: cabbage, radish, Anthomyiidae, *Delia radicum.* egg-laying, mechanical barriers, non-chemical control, larval mortality, larval penetration, collar, ash, *Sphagnum,* soil type, soil moistness.

## INTRODUCTION

The cabbage root fly, *Delia radicum* (L.), is an important pest of crucifer vegetables in Finland. It is controlled preventively by dressing the seeds or by drenching the roots of seedlings before planting (VARIS and TIITTANEN 1982). In the early 1900s, before the advent of pesticides, non-chemical, natural methods were widely used, e.g. barriers around the stems of young plants to deter egg-laying and to prevent the penetration of larvae through the soil into the roots. These old methods are now being re-examined (FINCH and WHEATLEY 1980, HAVUKKALA 1982, 1983) because of their potential as alternatives to the use of pesticides (e.g. MARKKULA and TIITTANEN 1982).

This report presents the results of laboratory experiments on the effects of mechanical barriers on egg-laying and larval penetration by *Delia radicum* under controlled laboratory conditions.

## MATERIAL AND METHODS

The experimental flies came from a culture of larvae sampled from radish in June 1980 at the Agricultural Research Centre, Vantaa (Grid 27°E 668:39, latitude 60°15'N) in the south of Finland. Larvae were reared on radish in pots of moist sand at 18 ± 2°C, 40—60 % R.H., LD 16:8. Species were determined at the pupal stage and transferred to emerging cages. Adult flies were given a dry diet, a sugar solution and pure water (cf. HAVUKKALA 1982).

Flies 9—10 days old were used in the oviposition tests. The experimental cages were 32 x 32 x 60 cm high, with net walls and wooden frames. Two plastic pots (16 cm high, Ø 12 cm) each with a 7-week, c. 15 cm cabbage seedling, variety Ditmarsker, were put into the opposite corners of the cage. The topmost 2 cm of the soil in the pot was sieved sand with a grain size of 1—3 mm. One pot was the control, the other had been treated by adding a 3 cm layer of air-dried *Sphagnum* moss to 4 cm from the plant stem or by placing a foam-rubber collar (8 x 8 cm and 3 cm thick) around the base of the plant.

Each cage contained 20 females and 15 males. The numbers of eggs laid at 0—3 cm and over 3 cm from the plant stem were counted every two days by the flotation method (cf. HAVUKKALA 1982) and a new layer of sand and a new barrier replaced. The locations of the plants in the cage were arranged at random in the four replicates and in the five successive examinations of each cage over 10 days.

Oviposition experiments with radish, variety Non plus ultra, were performed in the same way using 4-week, c. 7 cm plants in 10 cm x Ø 9 cm pots. The treatment consisted of sprinkling a 2—3 cm thick layer of wood ash (grain size < 0,6 mm) around the plants. Eggs were also counted from the leaf nodes, which were partly filled with ash in the treated plants.

The larval penetration of mechanical barriers was examined using pots 6 cm high and 9 cm in diameter, on the bottoms of which was a 3,5 x 3,5 x 1,5 cm piece of freshly cut swede, in a 2 cm layer of moist sand sieved to the grain size 1—3 mm. On top was a 3 cm layer of sand (control), ash, *Sphagnum* moss or a foam-rubber collar. The upper layer was either dry or moistened with 25 ml water. Ten eggs less than 3 days old were transferred onto the surface of each pot, which was then covered with plastic foil and kept at 18±2°C. After 15 days the number of larvae that had reached the swede and survived was counted.

## RESULTS

### Oviposition

The plant protected by a foam-rubber collar received 66 % fewer eggs than the control plants. Only slightly fewer eggs were found on moss-protected plants than on the control plants ($P < 0,1$), and ash had no effect (Table 1).

On untreated and moss-treated cabbage 89 % and 96 % of the eggs, respectively, were laid within 3 cm of the plant stem. On untreated and ash-treated radish 81 % and 95 % of the eggs, respectively, were laid within 3 cm of the plant stem. Only the foam-rubber collar caused a lateral shift in the site of oviposition; 57 % of the eggs were laid outside the barrier at distances > 4 cm from the stem.

Table 1. Oviposition of the cabbage root fly, *Delia radicum*, on cabbage and radish seedlings in the laboratory. Values are means ± S.E. of eggs/day/20 females during 5 successive counts at two-day intervals, n = 20. P gives significance of Wilcoxon's signed-ranks test for matched pairs.

| Treatment | Eggs ± S.E. | P |
|---|---|---|
| Cabbage | | |
| Control | 546 ± 60 | |
| Collar | 183 ± 37 | < 0,01 |
| Control | 298 ± 32 | |
| Sphagnum | 181 ± 17 | < 0,1 |
| Radish | | |
| Control | 287 ± 63 | |
| Ash | 345 ± 80 | N.S. |

On radish the ash treatment caused a statistically significantly larger proportion of egg-laying into leaf nodes; Wilcoxon test, T = 14, n = 16, P < 0,01 (Fig. 1).

**Larval penetration**

Analysis of variance showed that barriers varied in their penetrability and that dry barriers were more effective than moist ones. In the analysis the data was transformed to $\sqrt{x + 0,5}$ F = 24,5, n = 3, 24, P < 0,001 and F = 7,2, n = 1, 24, P < 0,013, respectively. Moss proved ineffectual, but dry collars and ash reduced the number of larvae found in the swede.

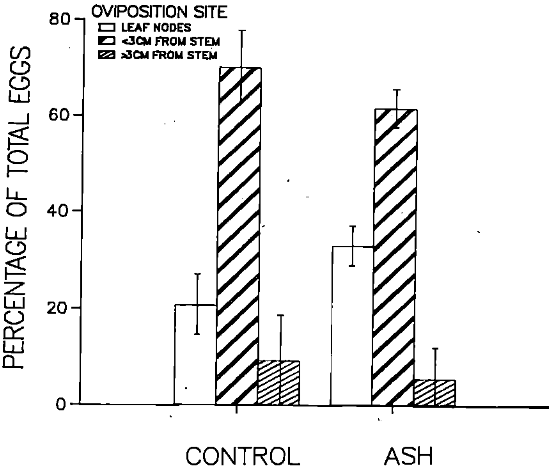

Fig. 1. Oviposition sites of cabbage root flies, *Delia radicum*, on radish c. 7 cm high with and without ash sprinkled around the stem. See text for details. Bars denote the proportion of the total eggs laid; vertical bars give the S.E. (n = 5, calculated from arcsin ($p^{1/2}$) transformed data).

| Substrate | Penetration in % dry | Penetration in % moist |
|---|---|---|
| Sand | 65a | 72a |
| *Sphagnum* | 62a | 63a |
| Collar | 13b | 33a |
| Ash | 0c | 18b |

The percentages have been corrected for egg mortality. Within each column different letters denote statistically significant differences; Mann-Whitney's U-test, n = 40, P < 0,05).

## DISCUSSION

The differences in the numbers of eggs laid in various barriers partly reflect their variable moistness. Moist substrates are sites of oviposition preferred by *D. radicum* (SCHNITZLER 1969, SÖMME and RYGG 1972). The foam-rubber collar worked best in reducing oviposition. However, in warm weather in the field, the protection offered by the foam-rubber collar against the desiccation of eggs and newly-hatched larvae may offset some of the controlling effect indicated in the laboratory experiments. About 26 and 35 % reductions in eggs found on collar-protected seedlings have been reported in field experiments (HAVUKKALA 1982).

The moistness of the soil is crucial for its penetration by larvae. According to READ (1965) only 5—10 minutes exposure to a dry substrate significantly lowered the mortality and survival of freshly emerged larvae. In the field the mortality of young larvae has been estimated to be 0—27 % (HUGHES and SALTER 1959) and 14 % (ZOHREN 1968).

The thickness of the soil to be penetrated before reaching the root is important, too. Only 50 % of *D. floralis* larvae are able to penetrate a 3 cm layer of sand (SÖMME and RYGG 1972), in contrast to 65—72 % of *D. radicum* in this study. Thus, a good mechanical barrier is one that makes the flies oviposit further from the main root, such as the foam-rubber collar.

The grain size of the soil also affects both the number of eggs laid (HAVUKKALA 1982) and the number of larvae penetrating to the roots: larvae find it easier to penetrate coarse sand. Field observations seem to support this, too: there tends to be less serious damage in clay fields than in sandy soils (e.g. REUTER 1901, WADSWORTH 1917, JÖRGENSEN 1957).

The poor penetration of the larvae through the ash layer may be due to direct toxic effects of the alkaline ash or to its small particle size (mechanical effect). Larvae may also fail to orientate themselves in a substrate that absorbs the attracting volatiles from the roots (biochemical effect). The latter explanation seems to hold at least for the wheat bulb fly, *Delia coarctata* (Fall.) (SCOTT and GREENWAY 1984). It might be possible to utilize this phenomenon by mixing charcoal into the soil around the cabbage roots, and thus increase the mortality of larvae by lengthening the time spent searching for the root after hatching.

## CONCLUSIONS

Laboratory experiments show that moss is unsuitable as an oviposition barrier. Ash is an effective barrier to larvae, but on radish may increase oviposition into the leaf nodes. The foam-rubber collar has the advantage of both reducing the number of eggs laid and displacing them laterally from the plant stem. Both the collar and ash seem suitable control methods against the cabbage root fly in small plots cultivated for home consumption.

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## REFERENCES

FINCH, S. & WHEATLEY, G.A. 1980. Physical barriers to protect cauliflowers from *Hylemyia brassicae* damage. Bull. SROP 3(1): 127—130.

HAVUKKALA, I. 1982. Deterring oviposition of the cabbage root fly, *Delia radicum* (Diptera: Anthomyiidae), by non-chemical methods. Acta Ent. Fenn. 40: 9—15.

— 1983. Naturliga bekämpningsmetoder mot kålflugor. Växtskyddsnotiser 46: 90—93. (English summary.)

HUGHES, R. D. & SALTER, D. D. 1959. Natural mortality of *Erioischia brassicae* B. (Diptera: Anthomyiidae) during the immature stages of the first generation. J. Anim. Ecol. 28: 231—241.

JÖRGENSEN, J. 1957. Den store kålflue *Chortophila floralis*. Fall. Ger. Stat. Fors. Virks. Pl.kultur 533: 657—712.

MARKKULA, M. & TIITTANEN, K. 1982. Possibilities of biological and integrated control of pests on vegetables. Acta Ent. Fenn. 40: 15—23.

READ, D. E. 1965. Rearing root maggots, chiefly *Hylemya* *brassicae* Bouchè (Diptera, Anthomyiidae in the greenhouse. Can. Ent. 97: 136—141.

REUTER, E. 1901. Kertomus tuhohyönteisten esiintymisestä Suomessa vuonna 1900. Maanvilj.hall. tied. 35: 1—41.

RYGG, T. & SÖMME, L. 1972. Oviposition and larval development of *Hylemya floralis* (Fallèn) (Dipt., Anthomyiidae). Norsk Ent. Tidsskr. 19: 81—90.

SCOTT, G. C. & GREENWAY, A. R. 1984. Effects of activated charcoal on attack by larvae of the wheat bulb fly, *Delia coarctata*. Ann. Appl. Biol. 104: 27—30.

SCHNITZLER, W. H. & MÜLLER, H. P. 1969. Über die Lockwirkung eines Senföls (Allylisothiocyanat) auf die Grosse Kohlfliege, *Phorbia floralis* Fallèn. Z. angew. Ent. 63: 1—8.

SÖMME, L. & RYGG, T. 1972. The effect of physical and chemical stimuli on oviposition in *Hylemya floralis* (Fallèn) Dipt., Anthomyiidae). Norsk Ent. Tidsskr. 19: 19—24.

VARIS, A.-L. & TIITTANEN, K. 1982. Insect pests of vegetables in Finland and methods for their control. Acta Ent. Fenn. 40: 38—42.

WADSWORTH, J. T. 1917. Report on a trial of tarred felt "discs" for protecting cabbages and cauliflowers from attacks of *Chortophila floralis*. Ann. Appl. Biol. 2—3: 82—92.

ZOHREN, E. 1968. Laboruntersuchungen zu Massenzucht, Lebensweise, Eiablage und Eiablageverhalten der Kohlfliege, *Chortophila brassicae* Bouchè (Diptera, Anthomyiidae). Z. angew. Ent. 62: 139—188.

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# SELOSTUS

## Munintaesteiden teho kaalikärpäsiä vastaan

ILKKA HAVUKKALA, MARTTI MARKKULA ja MARJA PIRILÄ

Maatalouden tutkimuskeskus ja Helsingin yliopisto

Kaalikärpäset ovat kaalikasvien pahimpia tuholaisia Suomessa. Niitä torjutaan nykyisin ennalta ehkäisten peittaamalla siemenet tai käsittelemällä esikasvatetut taimet torjunta-aineella istutuksen yhteydessä.

Viime vuosina Maatalouden tutkimuskeskuksen tuhoeläinosastolla on selvitetty biologisten ja bioteknisten menetelmien kehittämistä täydentämään ja korvaamaan kemiallisia torjuntakeinoja avomaan viljelyksillä. Tämä tutkimus on osa näistä selvityksistä.

Mekaanisten muninta- ja toukkaesteiden tehoa kaalikasvien suojaamiseksi kaalikärpästoukkien, *Delia radicum*, vioituksilta tutkittiin laboratoriossa. Keräkaalin ja retiisin suojaamiseen kokeiltiin 3 cm paksuja vaahtomuovikauluksia, rahkasammalta ja puutuhkaa taimen tyvelle ripoteltuna. Vain vaahtomuovikaulus vähensi munintaa selvästi. Tuhkan ripottelu retiisille lisäsi munintaa lehtihankoihin. Rahkasammaleella ei ollut vaikutusta munintaan, eikä se häirinnyt toukkien kaivautumista juuristoon. Kuivat vaahtomuovikaulukset ja tuhka sen sijaan estivät tehokkaasti vastakuoriutuneiden toukkien pääsyä juuristoon 3 cm:n syvyydelle.

Näiden tulosten ja aiemmin suoritettujen kenttäkokeiden perusteella rahkasammalsuojuksia ei suositella kaalikärpäsen torjuntaan. Sen sijaan huolellisesti asetetut vaahtomuovikaulukset ja riittävän usein toistettu tuhkakäsittely sopivat kaalikärpäsen torjuntaan kotipuutarhoissa. Retiisillä tuhkan teho saattaa olla riittämätön.

ANNALES AGRICULTURAE FENNIAE, VOL. 23: 176—182 (1984)

Seria PHYTOPATHOLOGIA N. 98 — Sarja KASVITAUDIT n:o 98

Research note

# RING SPOT OF *ARONIA MELANOCARPA*, A DISEASE CAUSED BY AN ISOMETRIC VIRUS TRANSMISSIBLE VIA SAP AND SEED.

KATRI BREMER

BREMER, K. 1984. **Ring spot of *Aronia melanocarpa*, a disease caused by an isometric virus transmissible by via sap and seed.** Ann. Agric. Fenn. 23: 176—182. (Agric. Res. Centre, Inst. Plant Pathol., SF-31600 Jokioinen, Finland.)

A virus disease which caused ring spot symptoms on the leaves of *Aronia melanocarpa* cv. Wiking was found in southern Finland. The virus could be transmitted with difficulty via sap from flowers and young leaves of *A. melanocarpa* to *Chenopodium murale* and *C. quinoa*. The virus was transmitted via seed in experimental infected *C. murale*, but not via soil. The virus infected 16 herbaceous plants and *Sorbus aucuparia*. *C. murale* and *C. quinoa* were suitable test plant. The virus was inactivated in sap at 60—62 °C, by diluting to $10^{-4}$, and after about 18 days storage at room temperature. The virus had isometric particles with a diameter of 29—30 nm.

The virus did not react to antisera against apple mosaic, *Prunus* necrotic ring spot, cucumber mosaic and seven NEPO viruses. The virus does not seem to spread easily in nature, because only one bush was infected in a period of ten years. The source of the virus is not known.

Index words: *Aronia melanocarpa*, isometric virus, ring spot, sap transmissible, seed transmissible, virus disease.

## INTRODUCTION

*Aronia melanocarpa* (Michx.) Ell. is a common ornamental plant in Finland. In Russia some cultivars of *A. melanocarpa* with big berries are cultivated for juice production. The department of Horticulture of Helsinki University introduced into Finland a cultivar, Wiking, which is suitable for berry production. The original material, about 20 bushes has been grown on Viikki farm since the early '70s. The propagation material for farmers was released through the Production Unit for Healthy Plants of the Agricultural Reseach Centre. The bushes were thus inspected twice a year and tested. All bushes were symptomless until August 1981, when ring spot symptoms were observed on a few branches of the bush. The symptoms spread quickly and in August 1982 the whole bush was infected.

*A. melanocarpa* has been experimentally infected with the apple stem grooving virus (van der MEER 1976) and with the apple chlorotic leaf spot virus (SWEET 1980), but as far as the author knows, this is the first report of a virus naturally infecting *A. melanocarpa*.

## METHODS

### Virus transmission

Graft transmissions to woody indicators were carried out by implanting a piece of bark beneath a bark flap in some test plants, and by grafting small twigs (bottle grafting) on some plants; 2—3 plants from each species were grafted in each way. Woody test plants originated from the Long Ashton Experimental Station and from the Swedish University of Agricultural Sciences, Institute of Plant Protection, Alnarp. Sap transmission from flowers and young leaves of *A. melanocarpa* was accomplished by manual inoculation to carporundum dusted, herbaceous test plants. Test plants were kept for 24 hours in a dark, cool place before and after inoculation. The inoculum was prepared by grinding flowers or leaves in 2 % nicotine in water. To prepare the inoculum from herbaceous test plants, 0,1 M phosphate buffer, pH 7,0 was used in the ratio 1 ml/mg leaves. Four or five plants of each species were inoculated and one plant inoculated with the buffer served as a control. Test plants were kept in a glasshouse and woody plants in a cool house during their dormancy.

### Soil transmission

Soil samples were collected at various depths down to 30 cm below the infected *A. melanocarpa* bush. Soil samples were mixed with sterilized soil in the ratio 1:1. Seeds of *Nicotiana tabacum, C. murale, C. quinoa* and *Cucumis sativus* were sown into the mixture.

### Properties *in vitro*

The sap for these tests was prepared from the leaves of *C. quinoa* inoculated 10—15 days earlier and showing the first systemic symptoms. The leaves were ground in 0,1 M phosphate buffer, pH 7,0 (1 mg/ml) and the sap was strained through double layers of muslin.

The dilution end point was determined by using tenfolds dilutions of sap from *C. quinoa* in phosphate buffer. The thermal inactivation point was determined by heating 2 ml lots of sap from *C. quinoa* at various temperatures for ten minutes in a water bath. Three tests were carried out using different times.

**Tests with antisera**. Sap expressed from infected *C. quinoa* leaves and mixed with phosphate buffer was tested against antisera with agar gel double diffusion tests. The gel contained 0,7 % Difco agar, 0,85 % NaCl and 0,02 % $NaN_3$. The wells were 5 mm in diameter and spaced 6 mm apart.

Antisera were kindly supplied by Drs. Arne Thompsen, Lyngby, Denmark, D. Z. Maat, Wageningen, Holland and J. I. Cooper, Oxford, United Kingdom.

**Electron microscopy**. Infected *C. quinoa* leaves were cut into 3—5 x 1 mm pieces, which were prefixed in 2,5 % glutaraldehyde in 0,1 M phosphate buffer for one hour at 5 °C. Fixed tissues were rinsed in phosphate buffer containing 0,5 % sucrose, postfixed for two hours with osmium tetroxide in 0,1 M phosphate buffer (pH

7,2). The sections were cut from Epon 812 embedded samples and stained with uranyl acetate and lead citrate. The sections were examined with transmission microscopes, Jeol 100 S and Jeol 100 B, operating at 80 kV, at the Department of Electron Microscopy, University of Helsinki.

## RESULTS AND DISCUSSION

### Virus transmission.

Sap transmission was attempted from flowers, leaves and berries of the infected *A. melanocarpa* bush using dithiocarbamate, mercaptoethanol and nicotine buffers. The transmission was successful, though with difficulty, from flowers and young leaves early in the spring and using nicotine as a buffer. Sap transmission was not successful at temperatures above 30 °C in glasshouse. Graftings on the *Rosaceae* plants grew well together and virus symptoms appeared early in the spring if the plants were grafted the previous autumn.

Seed transmission of the virus was tested from seeds of infected *C. murale*. Seeds collected at three different times and ground in phosphate buffer (2 ml/l g seeds) were inoculated into young *C. guinoa* plants. The test was repeated twice. Clear symptoms appeared in *C. quinoa.*

About sixty seeds of infected *C. murale* plants were grown for several weeks in the glasshouse. No symptoms appeared on the plants but the virus could be detected in them by sap transmission.

**Soil transmission.** Seedlings of *C. murale, C. quinoa, C. sativus* and *N. tabacum* were grown for two or three months in soil taken from beneath the infected bush. Sap transmissions on *C. quinoa* were carried out twice, one and two months after sowing, from roots of the test plants. No symptoms appeared in either test on *C. quinoa*. The occurrence of possible nematode vectors in this soil was not investigated, so nematode transmission of the virus is not excluded.

### Properties *in vitro.*

The virus was infective in *C. quinoa* sap after heating for ten minutes at 60 °C but not at 62 °C. The dilution end point was between $10^{-3}$ and $10^{-4}$. The virus remained infective at room temperature (18—23 °C) for 17—18 days.

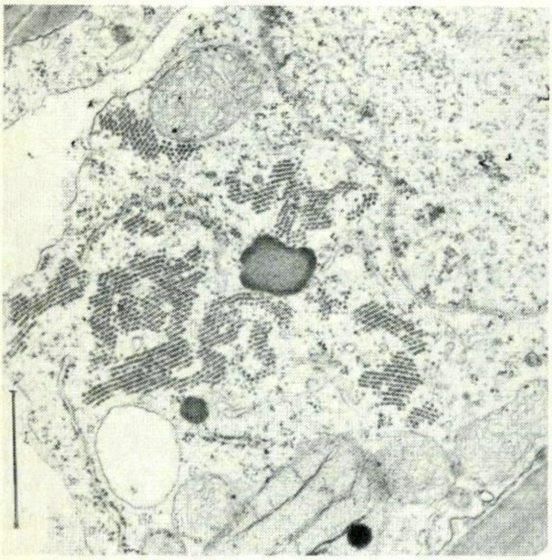
### Serological tests.

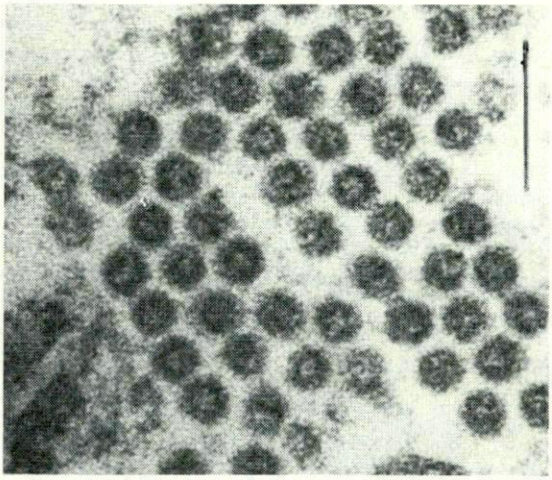
No reactions were obtained when infective sap from *C. quinoa* was tested in gel diffusion tests with antisera against the following viruses: apple mosaic, *Arabis* mosaic, cherry leaf roll, cucumber mosaic, *Prunus* necrotic ring spot, raspberry ring spot, strawberry latent ring spot, tobacco necrosis, tobacco rattle, tobacco ring spot, tomato black ring.

**Electron microscopy.** Electron micrographs of thin sections showed isometric particles in the cytoplasm. Particles were arranged in rows forming bigger groups. Only some cells contained particles. The diameter of the particles (50 particles measured) measured from the micrographs was 29—30 nm. (Figs. 1, 2.)

### Host plants and symptoms

The following plants were inoculated by grafting: *A. melanocarpa* (seedlings and cuttings of healthy plants), *Malus* x *domestica* cvs.: Cox Orange, Gravenstein, Lord Lambourne, Russian seedling R 12740 7A and Spy 227, *M. platycarpa, M. purpurea, Pyrus communis* cv. Beurre Hardy, seedlings of *Prunus avium, P.*





Figs 1 and 2. Electron micrographs of *Aronia* ring spot virus particles in cytoplasm. Bar represents 100 nm in Fig. 1 and 100 nm in Fig. 2.

*persica, P. padus, Sambucus racemosa, Sorbus aucuparia* and *Chaenomeles japonica*.

The following spring all inoculated *A. melanocarpa* plants showed clear and typical symptoms, which consisted of yellow, yellowish-green spots, lines and ring spots (Fig. 3). Symptoms appeared again every spring and remained clear during the whole summer. Also the bush that had been infected naturally, has been showing symptoms every summer. Flowers and berries have been normal. The number of berries was reduced. The size of the bush has not been greatly affected.

Spy 227 showed small, yellow spots on the youngest leaves. Other plants were symptomless. The virus could be recovered by sap transmission to *C. quinoa* or *C. murale* from the young leaves of *A. melanocarpa* and *S. aucuparia*. *S. aucuparia* was symptomless. Spy 227 showed symptoms, but the virus could not be recovered from it.

Twenty-two herbaceous plants were inoculated with sap from *C. murale* and *C. quinoa* : 16 species were infected and the virus could be recovered from them: the infection was latent in three species and seven species were not infected.

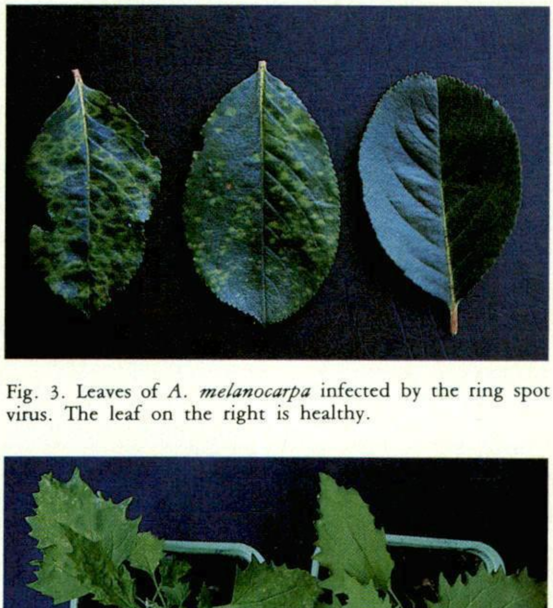


Fig. 3. Leaves of *A. melanocarpa* infected by the ring spot virus. The leaf on the right is healthy.

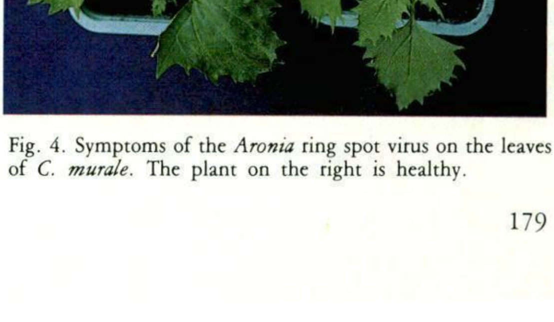


Fig. 4. Symptoms of the *Aronia* ring spot virus on the leaves of *C. murale*. The plant on the right is healthy.

Table 1. Herbaceous host plants of the *Aronia* virus

| Host plant species and cvs. | Local symptoms | Local symptoms appeared after inoculation in days | Systemic symptoms | Recovery of the virus from uninoculated leaves by sap transmission to *C. quinoa* |
|---|---|---|---|---|
| *Brassica napus oleifera* | — | — | — | + |
| *Capsicum annuum* | — | — | — | — |
| *Celosia argantea,* cv. Toreador | — | — | — | — |
| *Chenopodium amaranthicolor* | small, yellow spots which later grow together, forming large yellow spots | 6—7 | yellow spots | + |
| *C. foetidum* | — | — | — | — |
| *C. murale* | yellow dots and spots which enlarge, forming yellow areas (Fig. 4). | 5—6 | yellow spots, narrowing and twisting of the leaves, curling of the top | + |
| *C. quinoa* | yellow, sunken spots which enlarge into ring spots and later become necrotic with brown or red centres. Spots concentrate near the veins, which shorten and cause curling of the leaves | — | yellow spots, curling of the top and leaves | + |
| *Cucumis sativus,* cv. Arla | — | — | — | — |
| *C. sativus,* cv. Muromi | on the first leaves, round yellow spots with diameters 2—3 mm | 6—7 | — | + |
| *C. sativus*, cv. Suberb OE | — | — | — | — |
| *Cucurbita maxima*, cv. Vegetable Marrow | — | — | — | — |
| *Datura stramonium* | — | — | — | — |
| *Gomphrena globosa* | — | — | — | — |
| *Nicotiana clevelandii* | yellow mottling | 7—8 | yellow mottling | + |
| *N. glutinosa* | round, sunken, grey spots | 5—6 | yellow mottling and crinkle | + |
| *N. megalosiphon* | yellow mottling | 7—8 | faint mottling | + |
| *N. tabacum*, cv. Samsun | patterns of yellow, concentric ring spots and lines | 6—8 | patterns of yellowish green rings, spots and lines | + |
| *N. tabacum*, cv. White Burley | ring spots formed of necrotic dot lines | 8—9 | ring spots | + |
| *Petunia hybrida,* cv. Resisto Rosa | faint yellow mottling | 9—12 | yellow mottling | + |
| *Phaseolus vulgaris*, cv. Prelude | round, black ring spots | 4—6 | — | — |
| *Physalis floridana* | dark and yellow green mottling | 6—8 | — | + |
| *Solanum melongena,* | — | — | — | + |
| *Vinca rosea* | — | — | — | — |
| *Triticum aestivum*, cv. Linna | — | — | — | — |

Of three inoculated cucumber cultivar one was infected, but showed only local symptoms. The symptoms in herbaceous plants faded quickly if the temperature in the glasshouse remained near 30 °C for several hours per day. Futhermore the inoculation did not succeed on hot days.

The infected plant species and symptoms are presented in Table 1.

### Attempts to find the source of the virus.

As the *A. melanocarpa* bushes were symptomless for about ten years and the first infection occurred in 1981, the virus most probably came from the vegetation on Viikki farm. Besides other *A. melanocarpa* bushes grew next to the infected bush an apple tree and a little further on several apple, pear, plum and cherry trees. Several hundred metres away there were some *S. racemosa* bushes and *S. aucuparia* trees with ring spot symptoms. Several *P. padus* trees, which also grow in the vicinity, are all symptomless. To find the possible source of infection, some twigs were taken from these bushes and trees and grafted onto healthy *A. melanocarpa* plants. Symptoms appeared only in those *A. melanocarpa* plants on which twigs from *S. aucuparia* with ring spot symptoms were grafted. The symptoms consisted of spots, lines and ring spots undistinguishable from those caused by the *A. melanocarpa* ring spot virus. Sap transmission from *S. aucuparia* leaves with ring spot symptoms caused local spots on *C. quinoa* leaves. These symptoms in *S. aucuparia* were probably caused by the apple chlorotic leaf spot (cf. SWEET 1980), because the *A. melanocarpa* virus was latent in *S. aucuparia*.

According to the observations in plant nurseries which propagate ornamental cvs. from *A. melanocarpa*, the ring spot virus disease did not occur there. Random graft transmissions from ornamental *A. melanocarpa* plants did not reveal any virus infection either. So the *A. melanocarpa* ring spot virus is rare and does not seem to be of any economic importance at the present.

*Acknowledgements.* — The author is grateful to Mrs Kirsti Nieminen for her technical assistance.

## REFERENCES

MEER, F. A. van der 1976. Observations on apple stem grooving virus. Acta Hort. 67: 293—304.

SWEET, J. B. 1980. Fruit tree virus infections of woody exotic and indigenous plants in Britain. Acta Phytopath. Scient. Hung. 15: 231—238.

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# SELOSTUS

## Marja-aronian rengaslaikkuviroosi.

Katri Bremer

Maatalouden tutkimuskeskus

Valittaessa lähtöaineistoa tervetaimituotantoa varten Helsingin yliopiston Viikin marja-aroniapensaista (*Aronia melanocarpa*) havaittiin yhdessä pensaassa virustautia, joka aiheutti keltaisia tai kellanvihreitä pilkkuja, juovia ja rengaslaikkuja lehtiin. Marjojen lukumäärä oli vähentynyt sairaassa pensaassa.

Virus saatiin siirtymään puristemehussa marja-aronian kukista ja nuorista lehtistä *Chenopodium murale* ja *C. quinoa* testikasveihin, joista virus voitiin siirtää edelleen 15 ruohovartiseen kasviin. Oksaymppäyksellä virus siirtyi vain pihlajaan, se ei aiheuttanut pihlajassa oireita. Virus siirtyi siemenissä.

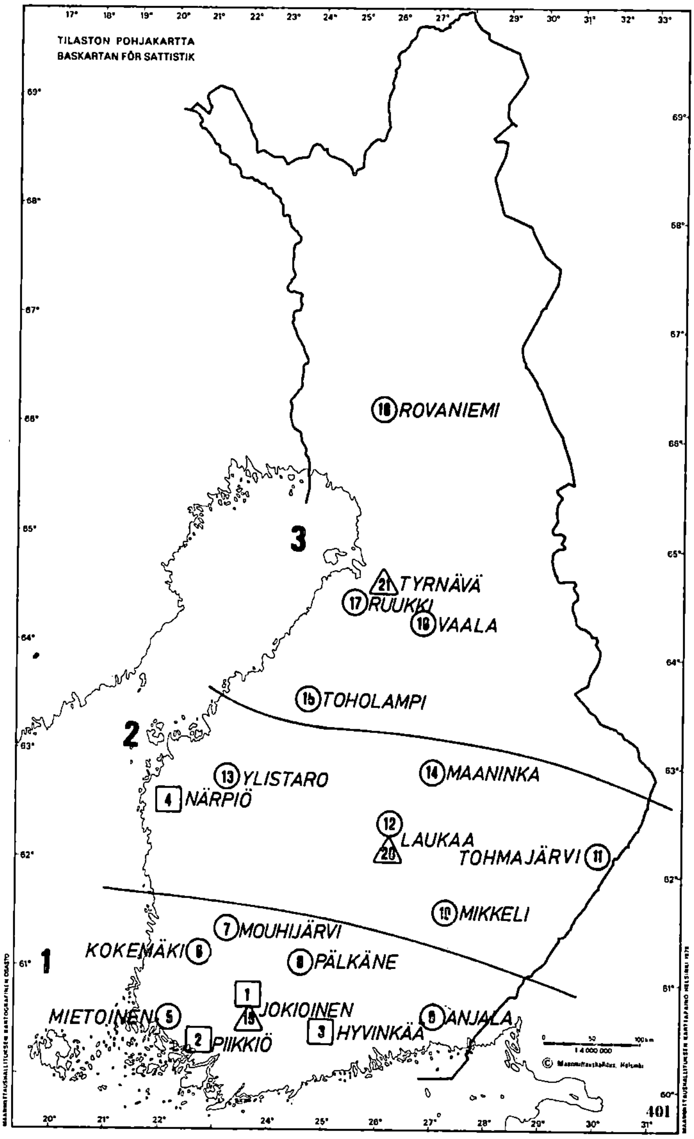
Viruksen lämmönsietoraja oli 60—62 °C ja laimennusraja $10^{-4}$. Virus säilyi infektiokykyisenä puristemehussa 17—18 vrk huoneenlämmössä.

Virushiukkaset ovat pyöreitä, 29—30 nm läpimitaltaan. Virus ei reagoinut *Prunus necrotic* ring spot-, omenan mosaiikki- eikä kurkun mosaiikkiviruksen antiseerumin kanssa. Myöskään seitsemän NEPO-ryhmän virusten antiseerumien kanssa ei ilmennyt positiivista reaktiota.

Marja-aronian rengaslaikkuviroosi näyttää leviävän hitaasti luonnossa, koska 10 vuoden aikana vain yksi pensas on saastunut. Taudin merkitys lienee hitaan leviämisen vuoksi vähäinen. Viruksen tartunnan lähdettä ei tunneta. Koristearonioista tautia ei tavattu.

Tämä on ensimmäinen tieto virustaudin esiintymisestä marja-aroniassa luonnossa.

# CONTENTS



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# CONTENTS — SISÄLTÖ

Helsinki 1985. Valtion painatuskeskus