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RESISTANCE OF PLANTS TO THE PEA APHID, ACYRTHOSIPHON PISUM HARRIS (HOM., APHIDIDAE)

IV. Fecundity on different alsike and white clover varieties

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In previous papers the authors have given accounts of the resistance of red clover and pea to the pea aphid *Acyrthosiphon pisum* Harris (MARKKULA and ROUKKA 1970, 1971). The purpose of the present study was to ascertain whether differences exist in the resistance of different varieties of alsike and white clover. Apparently, there have been no previous papers dealing with the resistance of these two clover species to the pea aphid.

Material and methods

The number of progeny of the pea aphid was studied on ten varieties of alsike clover and on twelve varieties of white clover. The culture of the test plants was arranged in the same way as in the previous tests on red clover (MARKKULA and ROUKKA 1970). The aphids belonged to three biotypes, originating from red clover: 1 a, 1 b and 16. The tests were carried out on newly mature wingless aphids in rearing cages, as in previous tests on the resistance of red clover (MARKKULA and ROUKKA 1970). There were twenty aphids of each biotype on each variety.

The varieties tested were as follows:

Alsike clover	White clover
Iso, 4n, Finland	Belyj N 13, USSR
Iso A, 4n, »	Culture Cebeco, Netherlands
Iso-67, 4n, Finland,	Esko, Finland
Jogeva 2, 2n, USSR	Jogeva 4, USSR
Perm Region, 2n, USSR	Kivi, Sweden
Rozovyi Region, 2n, USSR	Lubliana, Poland
Svea, 2n, Sweden	Morsö, Denmark
Tammisto, 2n, Finland	Nora, Sweden
Tetra, 4n, Sweden	Pajberg Milka, Denmark
Finnish commercial seed, 2n	Podkowa, Poland
	Tammisto, Finland
	Tammisto, Finland, grown for seed at Pälkäne

Results and discussion

Biotype 16 reproduced abundantly on all the varieties of alsike clover (Fig. 1). The number of progeny was least on the Swedish variety Svea, which showed a highly significant difference from all the other varieties tested. The number of progeny was greatest on the Finnish commercial seed. This »variety» differed very significantly from Svea as well as from Iso-67, Perm Region and Tetra.

The varieties were most resistant to the biotype 1 a. The average number of progeny was only 32 even on the most susceptible varieties, and there were no statistically significant differences between the varieties.

The fecundity of biotype 1 b on alsike clover was between those of biotypes 16 and 1 a. The

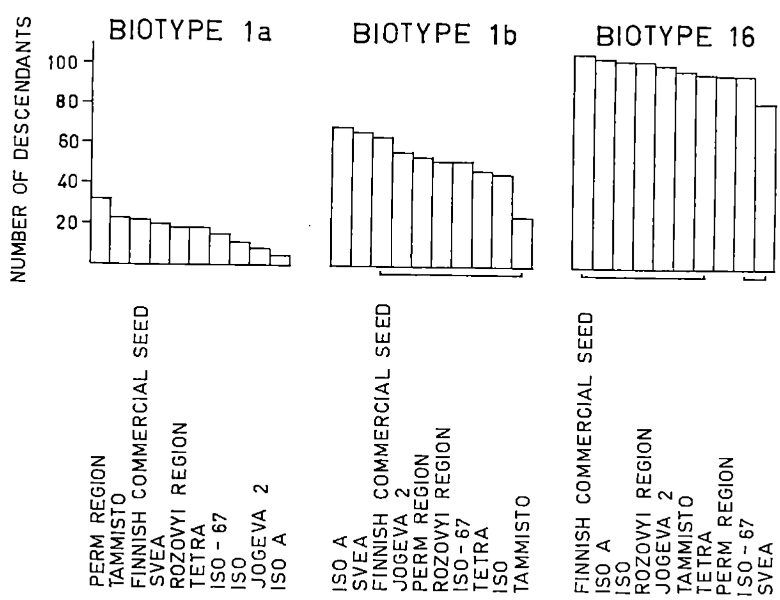

Fig. 1. Fecundity of biotypes 1 a, 1 b and 16 on different varieties of alsike clover. The heights of the columns indicate the average numbers of progeny on the varieties tested. Marks under the columns signify highly significant differences between the varieties ($P < 0.01$).

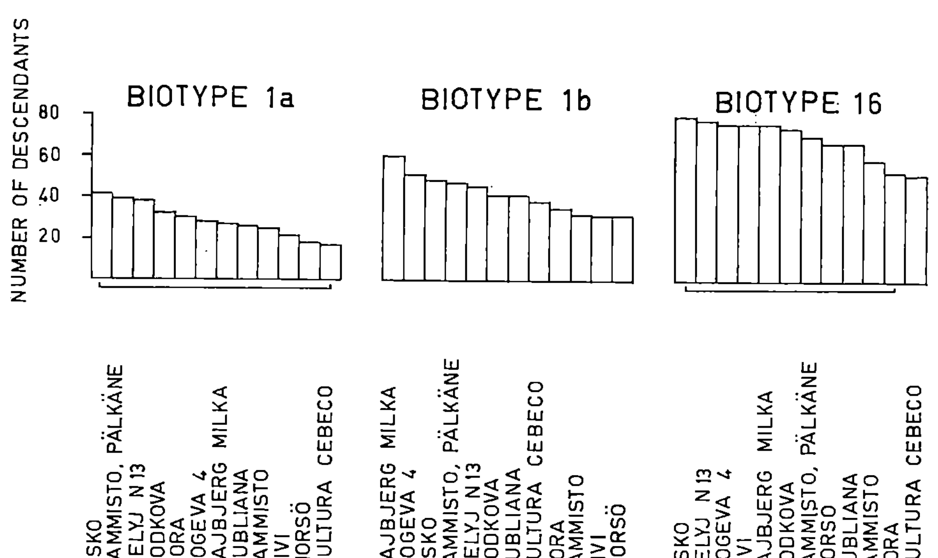

Fig. 2. Fecundity of biotypes 1 a, 1 b and 16 on different varieties of white clover. The heights of the columns indicate the average numbers of progeny on the varieties tested. Marks under the columns signify highly significant differences between the varieties ($P < 0.01$).

Tammisto variety proved to be the most resistant. The number of progeny on Tammisto was very significantly smaller than that on Iso A, Svea or on the Finnish commercial seed.

Biotype 16 was likewise most prolific on all the varieties of white clover (Fig. 2). The most susceptible variety was Esko. In the number of progeny produced by this biotype, Esko differed very significantly from Cultura Cebeco and Nora. Biotype 1 a was least prolific on all the varieties of white clover. The number of progeny of this biotype produced on Esko was very significantly greater than on Cultura Cebeco. The numbers of progeny of biotype 1 b were between those of biotypes 16 and 1 a. There were no significant differences in the number of progeny of biotype 1 b produced on different varieties.

The results distinctly indicated that the degree of resistance of the variety is dependent on the biotype of the pea aphid. The biotypes studied related to alsike and white clover in the same way as to red clover (see MARKKULA and ROUKKA 1970).

Summary

The fecundity of the pea aphid *Acyrthosiphon pisum* Harris was studied on ten varieties of alsike clover and on twelve varieties of white clover. The aphids belonged to three biotypes, originating from red clover: 1 a, 1 b and 16.

The results indicated distinctly that the degree of resistance is dependent on the biotype of the pea aphid. Judging from the number of progeny, all the varieties of alsike and white clover proved very susceptible to biotype 1 a. The varieties were considerably more resistant to biotype 1 b and most resistant to biotype 1 a. There were, in some cases, differences in the fecundity of the same biotype on different plant varieties.

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— 1971. III. Fecundity on different pea varieties. Ibid. 10: 33—37.

SELOSTUS

Kasvien kestävyydestä hernekirvaa vastaan

IV. Hernekirvan lisääntyminen eri alsike- ja valkoapilalajikkeissa

MARTTI MARKKULA ja KAISA ROUKKA

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Tutkimuksessa pyrittiin selvittämään alsike- ja valkoapilan resistenssiä hernekirvaa vastaan. Sitä varten tutkittiin hernekirvan kolmen biotyypin 1 a, 1 b ja 16 jälkeläismäärä 10 alsikeapilalajikkeessa ja 12 valkoapilalajikkeessa.

Biotyyppi 16 lisääntyi runsaasti kaikissa tutkituissa alsike- ja valkoapilalajikkeissa. Ainoakaan lajike ei osoittautunut resistentiksi sitä vastaan. Biotyypit 1 b ja 1 a lisääntyivät heikosti tutkituissa lajikkeissa. Kaikki lajikkeet osoittautuivat melko resistenteiksi biotyyppiä 1 b vastaan ja erittäin resistenteiksi biotyyppiä 1 a vastaan.

Tämän tutkimussarjan neljä julkaisua osoittavat, että tuhohyönteisten biologisten rotujen esiintyminen vaikeuttaa olennaisesti resistenttien kasvien jalostamista ja resistenssin hyväksikäyttöä kasvinviljelyssä.

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YMPÄRISTÖN LYIJYSAASTUMINEN TIKKURILASSA

Alustavia tutkimustuloksia

Summary: **Heavy local lead contamination in Southern Finland. Preliminary report**

ESKO LAKANEN ja RAIMO ERVIÖ

Maatalouden tutkimuskeskus, Maantutkimuslaitos, Tikkurila

Saapunut 16. 10. 1970

Elinympäristömme saastumisen tarkkailussa joudumme tutkimaan yhä useampia aineita ja saastetekijöitä. Aivan viime vuosina on kiinnitetty huomiota muutamien raskasmetallien määrän tarpeettomaan tai haitalliseen lisääntymiseen elinympäristössämme. Eniten on analysoitu elohopeaa ja lyijyä. Useissa tutkimuksissa on 1960-luvulla todettu teollisuusseutujen ja vilkkaasti liikennöityjen teiden ympäristöstä kerättyjen näytteiden sisältävän poikkeavan korkeita lyijymääriä. Syynä lyijyn leviämiseen luontoon ovat näissä tapauksissa olleet erilaiset metalliteollisuuslaitokset ja lyijy-yhdisteiden käyttö moottoribensiinissä.

Autobensiinissä alettiin lyijy-yhdisteitä käyttää bensiinikaasun puristuskestävyyttä lisäävänä aineena 1920-luvun alussa Yhdysvalloissa. Autokannan lisäännyttyä viime vuosikymmeninä huimaavasti on teiden varsille levinneen lyijyn määriä tutkittu useissa maissa (CANNON ja BOWLES 1962, LEH 1966, SALMI 1969, QUINCHE ym. 1969).

Lyijypitoisuuden on autoväyliä lähestyttäessä todettu nousevan sekä maa- että kasvinäytteissä. Bensiinistä peräisin oleva lyijy on levinnyt luontoon satojen metrien etäisyydelle, pisimmälle vallitsevien tuulten alapuolella. Teollisuus ja liikenne levittävät nykyään Etelä-Ruotsissa lyijyä 0.4—0.5 kg/ha vuodessa (RÜHLING ja TYLER 1970). Analysoimalla lehtisammalta aina 1860-luvulta peräisin olevista näytteistä lähtien ovat ruotsalaiset tutkijat voineet osoittaa, miten Pb-pitoisuus on voimakkaasti noussut teollisuuden kasvun ja autojen lisääntymisen mukana (RÜHLING ja TYLER 1968).

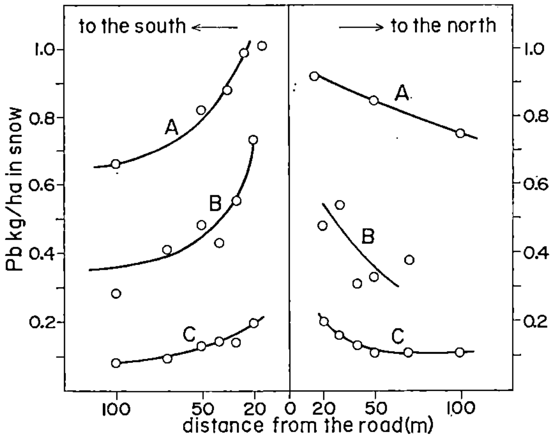
Ympäristöönsä voimakkaasti lyijyä levittäviä teollisuuslaitoksia ovat ennen kaikkea lyijysulattamot, varsinkin silloin, kun ne laskevat savukaasunsa puhdistamattomina ulos. Erään Neuvostoliitossa olevan lyijysulattamon ympäristössä todettiin lyijyä 0.5 km:n päässä yli 11 000 mg/kg maata ja vielä 40 km:n etäisyydellä 30 mg/kg maata (SMOKOTNINA 1962), mikä vielä viittaa kohonneeseen lyijypitoisuuteen, jos sitä verrataan maaperän Pb-pitoisuuteen 16 mg/kg maata. Teollisuus ja liikenne lisäävät näin ollen nykyään ympäristön lyijypitoisuutta siinä määrin, että ainakin paikallisesti juomaveden, maataloustuotteiden ja elintarvikkeiden lyijypitoisuudet saattavat ylittää kansainvälisessä käytössä olevat normit.

Tikkurilassa on useitakin lyijyä käsitteleviä teollisuuslaitoksia, ja koska Maatalouden tutkimuskeskuksen alueen lähinaapurina toimii lyijysulattamo, suoritti Maantutkimuslaitos alustavan tutkimuksen ympäristön lyijysaastuneisuudesta. Tutkimus aloitettiin luminäytteiden analysoimisella, mikä tarjoaa eräitä selviä etuja. Luminäytteen avulla on helppo määrittää tietyn ajan kuluessa tullut laskeuma. Näytteen koko on rajoittamaton, jolloin voidaan analysoida vähäisiäkin pitoisuuksia ja valita näytteenottopaikkoja mistä tahansa ulkosalta. Luminäytteiden keruuta ja analysointia on ennenkin suoritettu Suomessa ympäristötutkimusten yhteydessä (LAAMANEN 1968).

Tutkimusmenetelmät

Luminäytteet otettiin koko hangen paksuudelta muovisella sylinterillä, jonka halkaisija oli 15 cm ja pituus 80 cm. Näytteet kerättiin polyteenipusseihin, punnittiin ja suodatettiin sulamisen jälkeen. Suodos sekä suodatinpaperille jäänyt sakka analysoitiin erikseen. Näytteiden koko oli keskimäärin 5 kg, mikä on tarpeettoman suuri itse analyysia varten, mutta katsottiin tarpeelliseksi luotettavan pinta-alanäytteen saamiseksi.

Kaikki lyijymääritykset suoritettiin Techtron AA-4 atomiabsorptiospektrofotometrilla joko suoraan liuoksesta aallonpituuksilla 2170 Å ja 2833 Å tai rikastamisen jälkeen aallonpituudella 2833 Å. Luminäytteiden pienimpiä lyijypitoisuuksia määritettäessä käytettiin 20—30 -kertaista rikastusta, joka suoritettiin seuraavasti: Lievästi hapanta näyteliuosta (säilyvyyden takia lisätty HCl, pH 1—2) mitattiin punnitsemalla 500 tai 750 ml 1 litran mittapulloon. Lyijy ja useat muutkin raskasmetallit kelatoitiin lisäämällä 5 ml noin 0.5 *M* NaPDTC (pyrrolidinditiokarbamihapon Na-suola). Kelaatit ekstrahoitiin kolmella peräkkäisellä MIBK-ravistelulla (metyylisobutyyliketoni) 25 ml:n mittapulloon, joka täytettiin merkkiin MIBK:lla. Ensimmäisellä ravistelukerralla lisättiin noin 15—20 ml MIBK:ta. Kahden minuutin ravistelun jälkeen mittapullo täytettiin kapeaan kaulaosaan saakka ioninvaihtajalla puhdistetulla vedellä ja MIBK -faasi pipetoitiin 25 ml:n mittapulloon. Ekstraktio toistettiin kaksi kertaa 5—10 ml:n MIBK -erillä. Jo ensimmäinen ekstraktio antaa käytännöllisesti katsoen kvantitatiivisen saaliin, joten lyijy voitaisiin määrittää vedellä täyttämisen jälkeen atomiabsorptiotekniikalla suoraan mittapullosta, kuten kirjallisuudessa on suositeltukin (SLAVIN 1968). MIBK liukenee kuitenkin jonkin verran veteen, ja liukoisuus kasvaa veden lämpötilan aletessa. Tästä



Kuva 1. Lumen (4 kuukautta vanha) lyijypitoisuus eri etäisyyksillä tiestä. A = Kuriiritie 0.5 km lyijysulattamosta, B = Ohikulkutie 3.5 km sulattamosta ja C = Helsingin itäväylä 10 km sulattamosta.

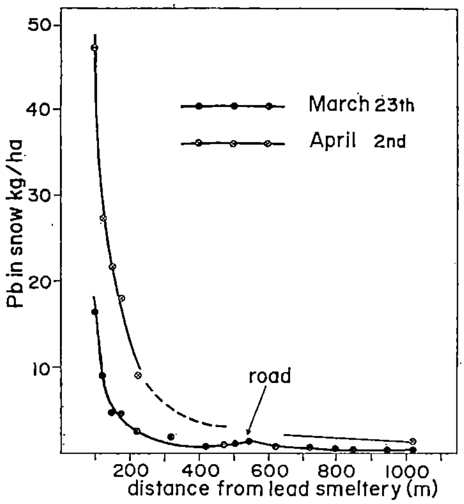
Fig. 1. Lead content of 4 months old snow at different distances from road. A = 0.5 km from a lead smeltery, B = 3.5 km from smeltery, C = 10 km from smeltery.

aiheutuva virhe eliminoituu, kun orgaaninen faasi siirretään 25 ml:n mittapulloon ja täytetään merkkiin. Peräkkäiset uutot varmistavat samalla kvantitatiivisen tuloksen. Sopiva standardisarja sisältää lyijyä 0, 2.5, 5.0, 7.5 ja 10.0 mg/l MIBK. MIBK -rikasteiden kvalitatiiviset analyysit suoritettiin ARL:n 2 metrin hilaspektrografilla.

Tulokset ja niiden tarkastelu

Luminäytteet otettiin maalis—huhtikuun vaihteessa 1970 Maatalouden tutkimuskeskuksen pelloilta eri etäisyyksiltä lyijysulattamosta sekä eri puolilta Tikkurilaa ja etäämmältäkin Helsingin maalaiskunnan alueelta. Liikenteen vaikutuksen selville saamiseksi analysoitiin luminäytteitä myös Ohikulkutien varrelta Helsingin pitäjän kirkon kohdalla sekä Itäisen moottoritien varrelta Helsingin Puotinharjusta. Lumipeite oli näytteenottoaikaan 4 kuukauden ikäinen. Pysyvä lumi satoi Seutulaan 24. 11. 1969.

Kvalitatiivinen spektraalianalyysi osoitti, että vilkkaasti liikennöityjen teiden varsilla oli lumessa useita raskasmetalleja: Pb, Fe, Cu, Zn, Mn, Ni, Cd, V, Sn ja Cr. Tikkurilan luminäytteet



Kuva 2. Lumen (4 kuukautta vanha) lyijypitoisuus lyijysulattamon lähiympäristössä.
Fig. 2. Lead content of 4 months old snow in the vicinity of lead smeltery.

sisälsivät myös antimonia (Sb), mitä ei muista näytteistä löytynyt.

Teiden varsien lumen lyijypitoisuudet esitetään kuvassa 1 ilmaistuina kg/ha. Tuloksista nähdään, että itäisen väylän varrella Helsingissä on lyijypitoisuus alhaisin, vaikka sen liikennetiheys on moninkertainen Ohikulkutiehen verrattuna.

Tämän Helsingin alueelta valitun näytteenottokohdan vuotuinen lyijylaskeuma jää samalle tai alhaisemmalle tasolle kuin edellä mainittu Etelä-Ruotsin 0.4—0.5 kg/ha, varsinkin jos mennään 100—150 metrin etäisyydelle tiestä, missä lyijyn määrä on pudonnut lähes vakiotasolle. Ohikulkutien varrella lyijylaskeuma on 3—4 -kertainen Helsingin tasoon verrattuna, ja kun tullaan Tikkurilaan Maatalouden tutkimuskeskuksen alueelle 0.5—0.6 km:n etäisyydelle lyijysulattamosta, on lyijylaskeuma edelleen moninkertaistunut, vaikka liikennetiheys on vielä alhaisempi. Tästä vertailusta tullaan siihen tulokseen, että Helsingin maalaiskunnassa vallitsee suhteellisen voimakas lyijyn peruslaskeuma, joka kasvaa jyrkästi Tikkurilan aluetta ja siellä lyijyromua polttavaa laitosta lähestyttäessä. Tämä nähdään havainnollisesti kuvasta 2, josta ilmenee myös sääolojen vaikutus samoista pisteistä otettujen luminäytteiden lyijypitoisuuksiin. Räntäsade ja näytteenottolinjan jääminen tuulen alapuolelle yhdessä miltei nelinkertaistivat lumen lyijypitoisuuden vajaan kahden viikon kuluessa. Eri etäisyyksiltä tehtaasta otettujen 4 kuukauden ikäisten luminäytteiden lyijypitoisuuksiksi saatiin: 100—200 m 47—10 kg/ha, 1 km 1.1—1.3 kg/ha ja 2.5—3.5 km 0.3—0.2 kg/ha.

Voimakkaimman saastelaskeuman kohteeksi joutuneen pellon lumipeitteen analyysituloksista 100—225 metrin etäisyydellä lyijyromua polttavasta laitoksesta nähdään taulukosta 1 mm. seuraavaa: Sulaneesta lumesta suodatetun veden pH on vakiotasolla 5.10—5.25, ja ominaisjohtokyky kasvaa lievästi sulattamoa lähestyttäessä. Veteen liukenemattoman ja tuhkaksi poltetun jäännöksen määrä kasvaa selvästi tehdasta lähestyttäessä, samoin tämän sakan lyijypitoisuus 19.5:stä aina 51 %:iin. Valtaosa lyijystä aivan tehtaan välittömässä läheisyydessä on veteen liukenematonta. Vesiliukoisen lyijyn prosenttinen osuus kokonaislaskeumassa kasvaa kuitenkin

Taulukko 1. Lyijysulattamon lähiympäristön lumipeitteen analyysitulokset. Näytteenottoaika 2. 4. 1970.
Table 1. Analyses of snow in the vicinity of lead smeltery. Sampling time April 2, 1970.

Etäisyys lyijysulattamosta *Distance from lead smeltery*	Suodos *Filtrate*		Tuhka *Ash*		Lumen lyijypitoisuus *Lead content of snow*			
	pH	Ominaisjohtokyky *Specific conductivity*	mg/l	Tuhkan lyijy- % *Pb % in ash*	Veteen liukenematon *Water insoluble*	Vesiliukoinen *Water soluble*		Yhteensä *Total*
m		(10 × mmho)			kg/ha	mg/l	kg/ha	kg/ha
100	5.10	0.21	36.7	51.0	39.3	3.88	8.2	47.5
125	5.20	0.21	30.9	49.8	21.0	4.58	6.3	27.3
150	5.25	0.20	25.2	41.7	14.5	5.26	7.3	21.8
175	5.15	0.18	18.7	34.9	12.6	2.80	5.4	18.0
225	5.10	0.19	17.6	19.5	5.5	2.20	3.5	9.0

etäisyyden lisääntyessä. Sulaneesta lumesta suodatetun veden lyijypitoisuus on tällä alueella suuruusluokkaa 2—5 mg/l, mitä on pidettävä erittäin korkeana, kun sitä verrataan Lääkintöhallituksen juomavedelle sallimaan suurimpaan lyijypitoisuuteen 0.05 mg/l. Talven 1969—70 aikana lumipeitteestä todettua lyijyn kokonaislaskeumaa on myös pidettävä oloissamme ainutlaatuisen korkeana.

Samanaikaisesti luminäytteiden kanssa analysoitiin pistokoeluonteisesti muutamia 1968—69 otettuja maanäytteitä, kesän 1969 kasvinäytteitä ja talvella 1970 otettuja havupuiden neulasia. Näiden edellisinä vuosina pelloilta otettujen maanäytteiden suurimmat lyijypitoisuudet olivat: totaalimäärä yli 1 000 ppm ja helppoliukoinen määrä yli 100 mg/l maata, joita pitoisuuksia on pidettävä korkeina vastaaviin Suomen peltojen keskimääräisiin pitoisuuksiin 16 mg/kg ja alle 1 mg/l maata verrattuina. Myös kasvianalyysit osoittavat selvää saastuneisuutta (taul. 2), kun saastumattomien kasvien lyijypitoisuudet ovat vähän alle tai yli 1 mg/kg kuiva-ainetta kasvilajista riippuen.

Taulukko 2. Muutamien kasvinäytteiden lyijypitoisuuksia.
Table 2. Lead content of some plant samples.

Etäisyys lyijysulattamosta *Distance from lead smeltery* m	Kasvi *Plant*	Lyijypitoisuus mg/kg kuiva-ainetta *Pb content mg/kg dry matter*
150 330	Havupuiden neulaset *Needles of conifer trees*	1.500—2.000 610
130—160	Punajuuri *Red beet*	97—137
	Sipuli *Onion*	31—79
	Porkkana *Carrot*	20—24
360 420 1 200—1 500	Heinän siemen *Hay seed*	33—43 25 10—17
150	Kevätvehnä (jyvä) *Spring wheat (grain)*	7—10
170 600	Kaura (jyvä) *Oat (grain)*	5—6 3—3.5

Tiivistelmä

Lukuisten kevättalvella 1970 otettujen luminäytteiden analyysien perusteella voitiin varmasti todeta, että Tikkurilan keskusta ja eräät Maatalouden tutkimuskeskuksen koealueet olivat joutuneet teollisuuslaitoksen aiheuttaman voimakkaan lyijysaastelaskeuman kohteeksi. Pistokoeluonteiset maa- ja kasvinäytteiden analyysit paljastivat myös korkeita lyijypitoisuuksia ja osoittivat runsaasti lyijyä kumuloituneen viljeltyihin peltomaihin.

Luminäytteiden analyysien perusteella oli mahdollista tarkastella tiheään liikennöityjen teiden varsien lyijypitoisuuksia ja verrata niitä Tikkurilassa esiintyvään teollisuuden aiheuttamaan saastutukseen. Liikenteen aiheuttama lyijysaastutus oli merkityksetöntä todettuun teollisuuden aiheuttamaan lyijylaskeumaan verrattuna. Teiden varsilla todettiin bensiinin lyijyn selvästi levinneen 100—150 metrin etäisyydelle tiestä.

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SUMMARY

Heavy local lead contamination in Southern Finland

Preliminary report

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Tikkurila, Finland

In spring 1970 snow samples were collected from Helsinki and Tikkurila in Southern Finland and analyzed for lead. Sampling sites were chosen along roads and from around a lead smeltery in Tikkurila. The vicinity of this factory, in which leadbearing material is burned, was investigated in more detail.

Lead contamination caused by traffic extended 100—150 meters from roads. Contamination increased as the lead smeltery in Tikkurila was approached despite a simultaneous decrease in traffic density (Fig. 1). The heavy emission of lead in the vicinity of the smeltery and snow analyses are presented in Fig. 2 and Table 1. Lead content of 4 month old snow samples showed the following lead emission at various distances from the smeltery:

100—200 m : 47—10 kg/ha
1 km : 1.1—1.3
2.5—3.5 km : 0.3—0.2 »

Analyses of a few soil and plant samples (Table 2) gave more evidence of lead contamination in Tikkurila.

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Seria ANIMALIA NOCENTIA N. 53 — Sarja TUHOELÄIMET n:o 53

COMPARISON OF LEAFHOPPER FAUNAE IN CEREALS

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The present work links up with an extensive study of the leafhopper faunae of cereals, of which the part concerned with the seasonal variation in the fauna of spring cereals (RAATIKAINEN 1971 b) and a number of accounts of the ecology of individual species (e.g. RAATIKAINEN 1967, 1971 a) have previously been published.

The purpose of the present work is to describe the major features of the leafhopper faunae of various spring cereals, but some data for winter rye are also included. It was shown in the previous study (RAATIKAINEN 1971 b) that the number of leafhopper specimens and species in oats is highest in late June and early July, i.e., at the change from the early summer aspect to the high-summer aspect. The material for the present study was consequently gathered at precisely that time.

There are previous descriptions of the leafhopper faunae of various cereals, e.g. in Germany (KUNTZE 1937, AFSCHARPOUR 1960) and Sweden (JÜRISOO 1964).

Material and methods

Samples of leafhoppers were netted from various cereals in the parish of Laihia (c. 63°N and 22°E) from 27 June to 1 July 1960. The samples were taken from each of the cereals at seven sites at which oats, barley, spring wheat and winter rye had been sown almost adjacent to one another. Other material was gathered from spring cereals in the parish of Tammela (c. 60°45'N and 23°45'E) from 26 June to 11 July 1963. The latter samples were taken from 16 farms in the parish. Samples were taken from 25 fields of each cereal. On average, the samples were netted one day earlier from oats than from barley, and two days later from wheat than from barley. The material from Tammela represents a normal leafhopper faunae of various spring cereals, while the material from Laihia represents an experiment performed at seven sites. At Laihia observations were also made on the ecology of leafhoppers in the field, and investigations were made of the host plants of some of the species and the host plant selection of *Javesella pellucida*.

Samples were taken in good weather from fields untreated with insecticides, at a distance of no less than 5 metres from the edges of the fields. The field-net used for sampling has been described by HEIKINHEIMO and RAATIKAINEN (1962). The samples were taken with 200 net sweeps from each field at Laihia and 60 from each at Tammela. All the samples from Laihia were taken by one person, and all those from Tammela by another.

At Laihia there is one extensive area of cultivated land. The crops grown there were hay, largely timothy, and cereals. At Tammela the fields are rather small, the area being a typical Finnish area of cultivation. The main crops

Table 1. Abundance of leafhoppers in cereals at Laihia, and the significance symbols of the variance analyses (S).

	Abundance				S
	Oats	Barley	Wheat	Winter rye	
Macrosteles cristatus (Rib.)	1 767	1 226	629	138	***
M. laevis (Rib.)	445	166	108	3	**
Balclutha punctata (Thb.)	3	—	—	—	
Macustus grisescens (Zett.)	—	—	—	1	
Doliotettix pallens (Zett.)	106	37	160	45	***
Elymana sulphurella (Zett.)	1	—	—	1	
Paluda flaveola (Bh.)	2	2	1	1	
Deltocephalus pulicaris (Fn.)	—	1	—	—	
Psammotettix confinis (Db.)	69	73	107	29	**
P. alienus (Db.)	200	80	281	100	*
Diplocolenus abdominalis (F.)	260	146	532	161	**
Arthaldeus pascuellus (Fn.)	1	—	1	1	
Palus costalis (Fn.)	—	1	1	—	
Boreotettix serricauda (Kontk.)	10	9	11	1	**
Stiroma bicarinata (H.-S.)	28	20	24	3	**
Dicranotropis hamata (Bh.)	13	—	3	5	
Criomorphus albomarginatus Ct.	—	—	—	2	
C. borealis (J. Sb.)	1	—	—	—	
C. moestus (Bh.)	—	—	1	—	
Megadelphax sordidula (St.)	593	408	309	64	***
Xanthodelphax flaveola (Fl.)	6	1	5	2	
X. straminea (St.)	2	—	1	—	
Javesella pellucida (F.)	1 014	458	703	44	***
J. obscurella (Bh.)	9	3	3	1	
Nymphs of *Cicadelloidea*	12	11	35	193	
Total	4 542	2 642	2 915	795	***

there were cereals and hay, which included a fair amount of clover as well as timothy. At Laihia the weed flora of the sampling sites was very similar in all the cereals. In the spring cereals the commonest weeds were *Spergula arvensis*, *Galeopsis* spp. and grasses, the most abundant of which were *Phleum pratense*, *Agropyron repens*, *Deschampsia caespitosa* and *Poa* spp. In the winter rye it was largely the same species that were the most abundant, although the proportions were not the same. At Tammela there was a substantial variation in the weed flora of the various cereals. The most abundant weeds in the oats and barley, which were growing on more highly organic soils than the wheat, were *Spergula arvensis*, *Chenopodium album* and *Galeopsis* spp. In the wheat, growing on the most sandy and clayey soils, the chief weeds were *Chenopodium album*, *Galeopsis* spp., *Agropyron repens* and *Stellaria media*. In the oats the density of weeds averaged 539 specimens/m^2, but in the barley and the wheat there was only about half that density. The coverage of the stands was greatest in rye, and successively less in oats, wheat and barley, but the differences were not large. The height was greatest in rye, then in wheat, barley and oats. At Tammela, herbicides had been applied to 14 fields of wheat, 8 of barley and 6 of oats, the remaining fields being untreated. At Tammela the wheatfields had the largest acreages and the oatfields the smallest. The wheatfields were also in the largest clearings, and the oatfields in the smallest. At Laihia the fields of oats and barley were largest, but, owing to the method of sampling, all the fields were in clearings of the same size.

A logarithmic transformation was done on the data from Laihia prior to the statistical calculations. Use was made of variance analysis. The chi-square method was used on the data from Tammela. The statistical significance is indicated by asterisks as follows: *** = $P < 0.001$, ** = $P < 0.01$ and * = $P < 0.05$. A species containing above 16 % of the total number of all specimens was considered dominant, one containing 4—15.9 % influent and one below 4 % recedent.

Table 2. Abundance and frequency of leafhoppers in spring cereals at Tammela and the significance symbols of the χ^2 analyses (S).

	Abundance			S	Frequency %		
	Oats	Barley	Wheat		Oats	Barley	Wheat
Macrosteles cristatus (Rib.)	357	213	92	***	100	92	84
Streptanus sordidus (Zett.)	2	—	—		8	—	—
Doliotettix pallens (Zett.)	23	19	18		40	32	16
Elymana sulphurella (Zett.)	—	—	1		—	—	4
Paluda flaveola (Bh.)	—	—	1		—	—	4
Limotettix corniculus (Marsh.)	1	—	—		4	—	—
Graphocraerus ventralis (Fn.)	—	—	1		—	—	4
Deltocephalus pulicaris (Fn.)	3	—	—		12	—	—
Psammotettix confinis (Db.)	3	5	1		12	20	4
P. alienus (Db.)	1	2	2		4	8	8
Jassargus allobrogicus (Rib.)	2	5	—		4	8	—
Diplocolenus bohemani (Zett.)	—	1	—		—	4	—
D. abdominalis (F.)	15	17	8		24	36	16
Arthaldeus pascuellus (Fn.)	—	6	1		—	16	4
Palus costalis (Fn.)	1	1	2		4	4	4
Boreotettix serricauda (Kontk.)	9	10	2		20	28	8
Evacanthus interruptus (L.)	1	1	3		4	4	8
Eupteryx atropunctata (Gz.)	2	1	1		8	4	4
E. cyclops Mats.	1	—	—		4	—	—
E. notata (Ct.)	1	—	—		4	—	—
Philaenus spumarius (L.)	3	2	22		8	4	12
Achorotile albosignata (Db.)	—	1	—		—	4	—
Stiroma bicarinata (H.-S.)	4	—	7		16	—	8
Dicranotropis hamata (Bh.)	1	5	2		4	16	8
Criomorphus moestus (Bh.)	1	—	—		4	—	—
Megadelphax sordidula (St.)	6	4	2		24	8	8
Xanthodelphax flaveola (Fl.)	1	—	—		4	—	—
X. straminea (St.)	1	2	—		4	4	—
Javesella pellucida (F.)	1 550	556	463	**	100	100	100
J. dubia (Kb.)	2	2	3		4	8	12
J. obscurella (Bh.)	—	—	1		—	—	4
Nymphs of *Cicadelloidea*	8	4	6				
Total	1 999	867	639	***			

Results

The number of species of leafhopper did not vary among the different cereals. However, the total number of leafhopper specimens was clearly lower in the samples from rye than in those from spring cereals (Tables 1 and 2). At Laihia where the species of spring cereal were growing very near one another in the same clearing, there were no differences in the total numbers of leafhoppers in the samples taken from them. At Tammela, however, where the distribution of the cereals over the area of cultivation was normal, there was a very significant difference ($\chi^2 = 31.38$***) in the total numbers of leafhoppers obtained from the spring cereals, and there were clearly more leafhoppers in the oats than in the other spring cereals.

As for as the individual species of leafhopper are concerned, at Laihia there were fewer *Macrosteles cristatus*, *M. laevis*, *Psammotettix confinis*, *Boreotettix serricauda*, *Stiroma bicarinata*, *Megadelphax sordidula* and *Javesella pellucida* in the rye than in the spring cereals. There were fewer specimens of *Doliotettix pallens* in the barley and the rye than in the oats and the wheat. *Diplocolenus abdominalis* was less abundant in the rye and the barley than in the wheat. *Psammotettix alienus* was less numerous in the barley than in the oats and the wheat. At Tammela there were fewer specimens of *Macrosteles cristatus* in the wheat than in the other spring cereals, and fewer *Javesella pellucida* in the wheat and the barley than in the oats.

The proportion of males among the adults of the most commonly occurring species is shown

Table 3. Percentage of males of some leafhoppers in cereals at Laihia.

	Oats	Barley	Wheat	Winter rye
Doliotettix pallens	8	11	8	0
Psammotettix confinis ...	49	56	48	66
P. alienus	64	59	69	61
Diplocolenus abdominalis .	36	62	46	35
Boreotettix serricauda ...	60	33	45	0
Stiroma bicarinata	54	45	46	0
Megadelphax sordidula ..	42	51	47	36
Javesella pellucida	79	85	76	58

in Table 3 except for the *Macrosteles* species, the females of which could not be determined by species but are divided in the same ratios as their males. The sex ratio was close to 1 : 1 for several of the species. *Doliotettix pallens* formed an exception. The males were few in number but they migrated to the cereal fields about as actively as the females. *J. pellucida* was also a clear exception, because the males migrated to the cereals earlier than the females, and during egg laying the males were located higher up in the stand than the females and consequently were netted in greater numbers than the females. Both sexes of all the species mentioned in Table 3 migrated to fields of spring cereals.

At Laihia *Macrosteles cristatus* was dominant in all the cereals, *Javesella pellucida* in the spring cereals and *Diplocolenus abdominalis* in rye and wheat. Only *Megadelphax sordidula* was influent in all the cereals, although there were 3—4 influent species in each cereal. Even *Megadelphax sordidula* was only exceptionally influent in 1960 and 1961, when its abundance was at a maximum. There were 10—13 recedent species in the various cereals. At Tammela the situation was quite different. There *Javesella pellucida* was dominant in all the cereals and *Macrosteles cristatus* in oats and barley. The latter species was influent in the wheat, there being no other influent species in any of the cereals. But there were 18—22 recedent species.

Discussion

Most of the abundant species were found in smaller numbers in winter rye than in the spring cereals. At sampling time at Laihia the winter rye was 130 cm tall, the wheat 50 cm, and the barley and oats 40 cm, and the leafhoppers in the rye could consequently be more widely distributed even though the numbers of specimens per areal unit might be identical. For this reason, fewer leafhoppers were caught from the rye than from the spring cereals. However, another and perhaps more important reason was that fewer leafhoppers found their way to the rye than to the spring cereals. For instance, *Javesella pellucida*, which makes its way to the stands almost exclusively by means of flight, does not seem to alight on rye in equal numbers as on spring cereals. The same phenomenon was also seen in the field selection test, in which the insects had a choice of cereals, arranged in 2 separate sets of 4 plants of each species along the periphery of a circle 40 cm in diameter. In 1—2 days *J. pellucida* selected barley 74 times, oats 63, wheat 43 and winter rye 26 times. Few leafhopper species seem to show a strong preference for any particular spring cereal when migrating from the winter quarters. But normally *Macrosteles cristatus* and *J. pellucida*, for instance, occur in larger numbers on oats than on wheat owing to the fact that oats are grown in outlying fields, where, because of type of crop rotation and the composition of the cultivated plants, the frequency of these two species of leafhopper is higher than their frequency in the places where wheat is grown. No differences were found in the numbers of *J. pellucida*, for example, when spring cereals were grown adjacent, according to Table 1 and to RAATIKAINEN (1967, e.g. Tables 85 and 86).

The leafhoppers obtained from the cereal fields were almost without exception species that feed chiefly on cereal plants or on grasses growing as weeds, or are at least able to survive on the food they obtain from these plants, an example being *Philaenus spumarius*. Only about 1 % of the specimens were of species whose food is not known or which are unable to live on cereals. Examples of these are *Eupteryx atropunctata*, which lives e.g. on Labiates growing as weeds, *E. cyclops*, which lives on *Urtica* growing as a weed, and *E. notata*, which lives, for example on *Prunella vulgaris* and *Hieracium pilosella* growing as weeds (OSSIANNILSSON 1946). Of the species found in the cereal fields, the host plant species of *P. spumarius* are the best known (see e.g. HALKKA et al. 1967). For its food in the field this leafhopper usually consumes red clover and some dicotyledons growing as weeds. In cereal fields, too, it lives partly on weeds but is frequently found on the cereals.

Of the leafhopper species mentioned in the present study, *Macrosteles cristatus*, *M. laevis*, *Dicranotropis hamata*, *Megadelphax sordidula*, *Javesella pellucida* and *Javesella obscurella* have been demonstrated to be vectors of virus or mycoplasma in Finland (RAATIKAINEN 1970). In Sweden it has been found that *Psammotettix alienus*, too, is a vector (LINDSTEN, VACKE and GERHARDSON 1970), and this species must obviously transmit virus in Finland too, although it was not possible to investigate the matter when severe damage occurred to crops in 1918 (LINNANIEMI 1920, 1935). When these seven species are reckoned as vectors, the specimens of species established as vectors amounted at Laihia to 89.1 % of the leafhopper adults and nymphs on the oats, 88.8 % of those on the barley, 69.9 % of those on the wheat and 44.7 % of those on the rye. At Tammela the respective figures were 95.8 % on oats, 91.1 on barley and 87.9 on wheat. The most important vector among these is *J. pellucida*, which transmits oat sterile-dwarf virus (OSDV) and European wheat striate mosaic virus (EWSMV), and which contained many virus-transmitting specimens and had one of the highest dominances. *Macrosteles cristatus*, although abundant, was of very minor importance, for very few specimens of this species carry aster yellows in Finland. The most important virus economically was OSDV on oats, but EWSMV on oats and wheat is also economically important. The fecundity of the vectors of OSDV is high on spring cereals (e.g. RAATIKAINEN 1967), the nymphs acquire the virus, especially from oats, and the following year the adults transmit it (LINDSTEN 1961).

The material representing the high-summer aspect of the year on oats at Laihia (RAATIKAINEN 1971 b) and the changeover from early-summer to the high-summer aspect at Tammela reveals that these aspects at least are very similar in leafhopper composition in the various spring cereals. According to unpublished scattered samples, the late-summer aspect, too, is very similar, and it is thus probable that in Finnish spring cereals there is only one leafhopper community, which has previously been called the *Javesella pellucida — Macrosteles cristatus* community (RAATIKAINEN 1971 b). On account of the paucity of material it is not yet possible to compare the leafhopper community of winter cereals with that of spring cereals.

Summary

Samples of leafhoppers on cereals were netted in two parishes in western Finland at the turn of June—July. The samples contained a total of 36 determined species and more than 14 000 specimens. Of many of these species, fewer specimens were obtained from winter rye than from spring cereals. Of some of the species fewer specimens were obtained from barley and spring wheat than from oats. The total number of specimens was highest in the samples taken from oats.

Macrosteles cristatus was a dominant species in all the cereals, *Javesella pellucida* in the spring cereals and *Diplocolenus abdominalis* in the rye and spring wheat. Both sexes, at least of the most abundant species, migrated to the cereals. 89—96 % of the specimens in oats, 89—91 % of those on barley, 70—88 % of those in wheat and 45 % of those in rye were of the 7 species known to be vectors of cereal virus or mycoplasma in northwestern Europe.

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SELOSTUS

Viljojen kaskasfaunojen vertailua

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Tämä työ liittyy osana viljojen kaskastutkimuksiin, joilla pyritään selvittämään kaskaiden ja niiden levittämien virusten ja mykoplasmojen viljoille aiheuttamia vioituksia ja torjuntaa.

Aineisto kerättiin haavilla kesä—heinäkuun vaihteessa v. 1960 Laihialta ja v. 1963 Tammelasta. Näytteissä oli yhteensä 36 määritettyä kaskaslajia ja 14 399 yksilöä. Useita lajeja saatiin syysrukiista vähemmän kuin kevätviljoista. Eräitä lajeja saatiin myös ohrasta tai kevätvehnästä vähemmän kuin kaurasta. Kokonaisyksilömäärä oli kaurasta otetuissa näytteissä suurin. Runsaimpina lajeina oli kaikissa viljoissa viljan kääpiökaskas (*Macrosteles cristatus*) ja kevätviljoissa viljakaskas (*Javesella pellucida*). Viljojen virus- tai mykoplasmavektoreiksi Pohjoismaissa todettujen seitsemän lajin yksilöitä oli kaurassa 89—96, ohrassa 89—91, vehnässä 70—88 ja rukiissa 45 % kaskaiden koko yksilömäärästä.

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THE EFFECTS OF SOIL FACTORS ON THE UPTAKE OF RADIOSTRONTIUM BY PLANTS. PART III

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In previous experiments it was found that the relative uptake of radiostrontium by plants, expressed as the Sr/Ca ratio, decreased with a) increasing soil pH, b) increasing content of exchangeable Ca in soil, c) increasing content of exchangeable inactive Sr in some cases, d) increasing clay content and e) increasing organic matter content (LAKANEN and PAASIKALLIO 1968, 1970).

In the most recent studies the amount of organic matter has been found to be the most important of these factors; increasing the organic matter content in a finesand from 0 to 15 per cent reduced the Sr 89/Ca ratio of plants by a factor of 3. In view of this, it was decided to undertake a detailed study of the effect of organic matter quality upon the uptake of radiostrontium.

Pot experiments with oats were carried out with some Finnish peat types differing from each other in their degree of decomposition, with bark humus, which is a decomposition product of conifer bark, and with fractionated organic materials. These last included humin and humic acids mixed with finesand in varying proportions.

Materials and methods

The types of peat soils were: two Sphagnum peats, one of which was a top soil, the other deeper in the same bog, Carex peat, Ligno Carex peat and bark humus, a commercial fertilized decomposition product of conifer bark.

The air-dried and ground Carex peat was fractionated according to KONONOVA (1966). The peat was extracted with 0.1 N NaOH for two days. The insoluble residue was humin. The solution was acidified with H_2SO_4 to pH 2—3, at which the humic acids precipitated and the fulvic acids remained in solution. The extraction was repeated. Humin and humic acids were washed with deionized water, air-dried and ground. Humin was mixed with finesand in such ratios that the final carbon percentages of the soils were 0.04, 0.22, 0.43, 1.68 and 2.87. The carbon percentages of the soils to which humic acids were added were 0.04, 0.19, 0.38, 1.47 and 2.51. The amount of fulvic acid obtained during fractionation was so small that no trials were made with additions of fulvic acid. Mechanical fractionation of the finesand gave the following composition 0.02—0.06 mm 5.0 %, 0.06—0.2 mm 45.9 %, 0.2—0.6 mm 37.3 %, and 0.6—2.0 mm 11.8 %.

Some characteristics of the substances tested are given in Table 1. The fertilization of all the soils was the same as in the previous work (LAKANEN and PAASIKALLIO 1968). The peat

Table 1. Characteristics of the organic material used in pot experiments.
Taulukko 1. Astiakokeissa käytetyn orgaanisen aineksen ominaisuudet.

Type of organic material	C %	N %	C/N	Volume weight g/ml	Humic acid %	CEC meq/100 g (meq/l)	pH	Exchangeable ppm Ca	Mg	K
Bark humus, B	48.3	0.53	91.1	0.230	0.7	81.0 (186.3)	5.50	2 025	180	510
Sphagnum peat, Sp (H_3) ...	49.1	1.02	48.1	0.145	3.9	173.6 (251.7)	4.15	400	55	20
Carex peat, Cp (H_{3-4})	52.1	1.65	31.6	0.175	18.6	127.6 (223.3)	4.35	510	61	24
Ligno Carex peat, LCp (H_6)	48.3	2.21	21.9	0.290	32.8	113.7 (329.7)	4.30	1 000	144	45
Sphagnum peat, Sp (H_{6-7})	49.8	1.61	30.9	0.330	21.3	107.4 (354.4)	4.00	500	85	20
Humin	43.8	0.89	49.2				7.40	260	280	70
Humic acid	38.4	1.77	21.7				1.00	40	10	20

soils were limed with $CaCO_3$, so that the content of exchangeable Ca was about 2 200 mg/litre of soil. Bark humus was neither fertilized nor limed. The pH of the soils varied from 5.5 to 6.2, only Ligno Carex peat having a lower value, 4.5. Lime was added to the humin and humic acid soils at a rate of 1 200 mg Ca/litre of soil. An attempt was made to adjust the pH and exchangeable Ca of each soil with experimentally determined quantities of $CaCO_3$ and $CaCl_2$. It was not possible to obtain similar levels of both calcium and pH in all the humin and humic acid soils. The pH values of the humin soils varied from 6.6 to 7.5 and of the humic acid soils from 6.6 to 5.0, both with increasing carbon content.

The quantity of neutral, carrier-free Sr 89 added to the peat soils and bark humus was 80μCi/l of soil. 50 μCi/l of soil was added to the soil series with increasing organic matter content. Oat seeds were sown in the various soils in plastic pots with four replicates and the plants were harvested after a month. The analytical and counting methods have been reported in Part I. Visual estimates of the degree of decomposition in the peat soils were made according to a peat scale of advancing decomposition ranging 1—10.

Results and discussion

Experiments with peat soils

Fig. 1 shows the Sr 89/Ca ratio in the plants plotted against the increasing degree of decomposition of the peat soils. Bark humus appears first in this graph on account of its other properties, because its degree of decomposition cannot be estimated on the peat scale. The Sr 89/Ca ratio in the plants was found to decrease with progressive decomposition of the soils. In Fig. 2 three important characteristics of peat soils are plotted against the progressive decomposition of the soils. The carbon-nitrogen (C/N) ratio decreases and the content of the humic acids increases as decomposition advances. The cation exchange capacity (CEC) of the soils, expressed in meq/l, also increases with increasing degree of decomposition.

When organic matter decomposes, essential changes occur in its chemical and physical properties and in its biological activity. The volume weight increases with increasing decomposition (Tuorila 1928). The volume weight is, however, nearly as rough an estimate of the degree of decomposition as the visual »peat scale» method.

The C/N rations in the peats under study vary with the estimated values of the degree of decomposition except in the case of the two most decomposed peats, and the Sr 89/Ca ratio of the plants decreases with decreasing C/N.

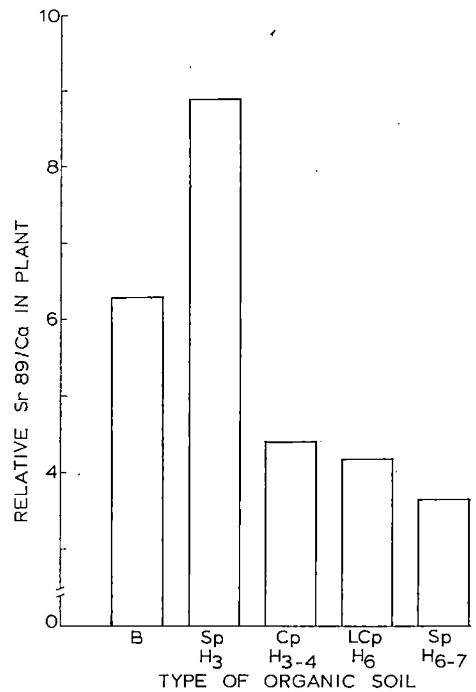

Fig. 1. The Sr 89/Ca ratio in plants growing in organic soils of different degree of decomposition.
Kuva 1. Kasvien Sr 89/Ca -suhde eri maatumis-astetta edustavilla turvemailla.

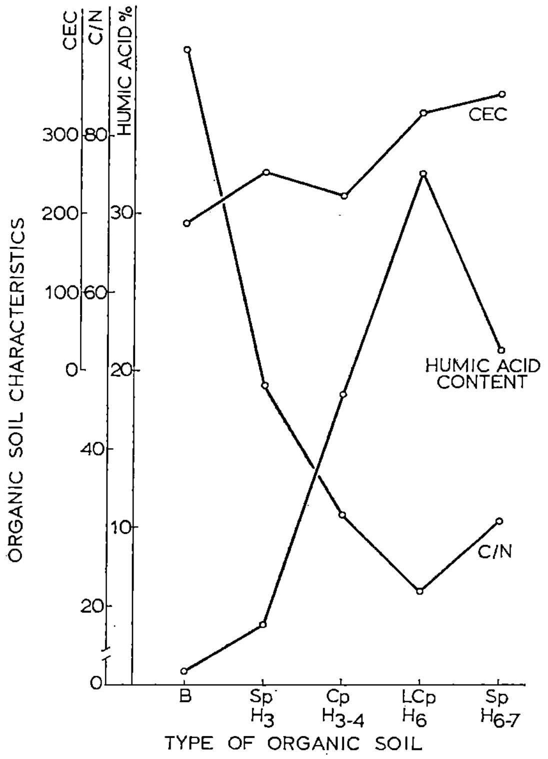

Fig. 2. The change in CEC, C/N and humic acid content of organic soils with increasing degree of decomposition.
Kuva 2. Turvemaiden CEC:n, C/N:n ja humushappopitoisuuden muuttuminen maitten maatumisasteen kasvaessa.

The decomposition of plant residues is chiefly brought about by microorganisms, chemical degradation of carbohydrates probably being important only under exceptional soil conditions, e.g. in acid peats. The amount of nitrogen in soils tends to be related to the amount of organic carbon. Owing to microbial activity the carbohydrates of plant residues decrease, and the organic nitrogen shows a relative increase. Plant residues have a C/N ratio of about 30 : 1. Because microorganisms are unable to assimilate all the organic carbon of the plant residues as they can the nitrogen, the excess carbon is eliminated as CO_2 or, in anaerobic or acid conditions, partly accumulated as carbonaceous material, i.e. soil organic matter (Campbell and Lees 1967). In general, the decrease in the C/N ratio of soil indicate the extent of its decomposition. But the average nitrogen content of Sphagnum peats is less than that of other peat types, and thus the type of peat may also affect the C/N ratio (Kivinen 1934 and Puustjärvi 1955, 1961).

The cation exchange capacity of peats is considerably higher than that of mineral soils. Expressed in meq/100 g, the highest value has been found for Sphagnum peat in an early stage of decomposition. It is recommended (Puustjärvi 1969) that the CEC of peat cultures should be expressed in meq per unit volume. These values, which increase with advancing decomposition, are also shown in Table 1. They possibly make it easier to understand the behaviour of peat soils in pot experiments. It is assumed that the carboxyl and phenolic hydroxyl groups of organic matter are mainly responsible for its cation exchange properties (Broadbent and Bradford 1952). As organic matter decays, the amount of colloidal matter increases, and since

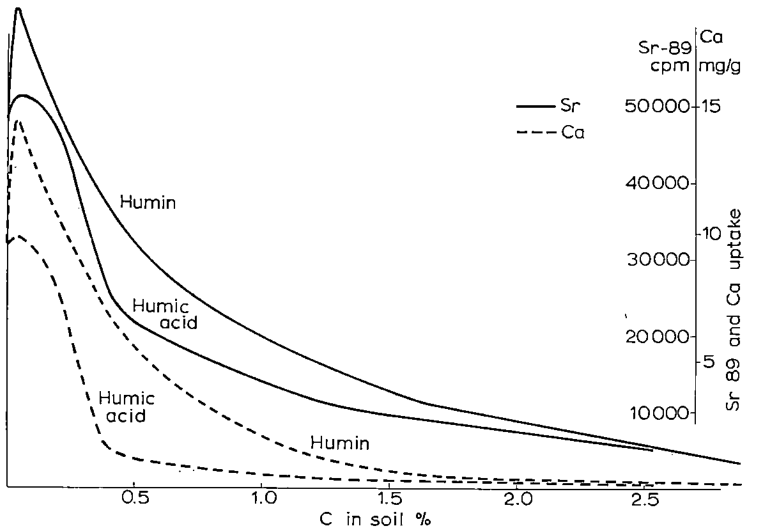

Fig. 3. The effect of organic matter on the uptake of calcium and radiostrontium by plant.
Kuva 3. Maan orgaanisen aineen pitoisuuden vaikutus kasvin kalsiumin ja radiostrontiumin ottoon.

it forms the most active part of the soil, a simultaneous rise of CEC would be expected.

Our experiments showed that as the humic acid content of soils was increased, the CEC increased. This lends support to the above-mentioned assumption that the exchange groups of organic matter reside in the humic acids and other humus substances. The tendency of the Sr 89/Ca ratio of plants to decrease as the content of humic acids increases indicates that the exchange groups of organic matter are responsible for the relative uptake of Sr and Ca cations by plants. Ligno Carex peat has the highest content of humic acids, while both bark humus and Sphagnum peat (H_3) differ remarkably from the other peats in their lower content of humic acids. Lignin and flavonoid residues are suggested to contribute to humic acids (Hurst and Burges 1967). Mosses contain very little lignin, while grasses, and especially wood, are rich in it (Kononova 1966 and Puustjärvi 1969). The high content of humic acid in Ligno Carex peat compared to that of Sphagnum peat at a comparable stage of decomposition may be due to the higher lignin content of the former. On the other hand, there are highly conflicting reports on the possible contribution of cellulose and other carbohydrates to the formation of humus substances (Kononova 1958, 1966).

The dry matter yield of oats grown on peat soils increased with increasing content of soil humic acids and was consequently highest when Ligno Carex peat was the growth substrate. Reports indicating the favourable effects of small amounts of humic substances on the growth of plants have been made, and have been reviewed by Kononova (1966).

From the above observations on different peat soils, it can be concluded that the degree of decomposition of the peat affects the relative uptake of Sr 89 and Ca by plants; the more decomposed the peat, the lower the Sr 89/Ca ratio of the plants. In the definition of the concept of decomposition of peat soils, the important characteristics were found to be the C/N ratio, the CEC and the humic acid content. The C/N ratio was found to decrease and the humic acids and CEC to increase with advancing decomposition.

Experiments with humin and humic acid soils

In Fig. 3 the values for Sr 89 and Ca uptake and in Fig. 4 the Sr 89/Ca ratio are plotted against the soil carbon content. The amounts of Sr 89 and Ca taken up by oats decrease with increasing soil carbon content. However, the Ca content of the plant decreases faster than the Sr content, so that the Sr 89/Ca ratio increases with increasing carbon content of the soil. Perhaps the organic matter did not decrease the Sr 89/Ca ratio of plants at the low organic matter contents used in this experiment. From Fig. 4 it is seen that in the humin and humic acid soils the Sr 89/Ca ratio begins to decrease when the carbon content of the soil is at its highest. These results do not agree with those of our earlier experiments with peat soils. Possible causes of this discrepancy should be studied.

Carboxyl groups are the chief exchange sites in humic acids and humin. They largely determine the Ca—Sr exchange equilibria and the plant uptake of these ions (Khasawneh et al. 1968, Juo and Barber 1969 and McLean et al. 1969). Chemical fractionation and drying may denature humin and humic acids and change their physico-chemical properties, for example the exchange capacity (Puustjärvi 1955, 1956 and van Dijk 1966). Changes in pH values, especially in humic acid soils may have some effect on the sorption of Sr 89 by the soil compared with that of calcium (Schroeder et al. 1962).

In some acid soils rich in organic matter Sr 89 reaches isotopic equilibrium slowly, in not less than one month (Taylor 1969). Calcium may approach equilibrium somewhat more rapidly than strontium. If strontium has not reached complete equilibrium before the crop is planted, there may be selectivity in soil sorption and plant uptake between Sr 89 and Ca.

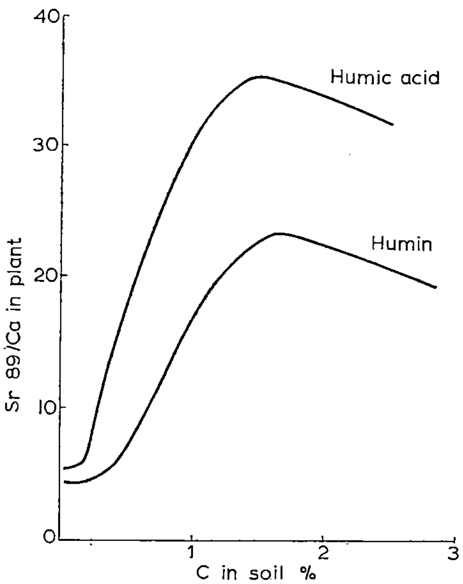

Fig. 4. The effect of organic matter on the Sr 89/Ca ratio of the plant.
Kuva 4. Maan orgaanisen aineen pitoisuuden vaikutus kasvin Sr 89/Ca -suhteeseen.

Summary

The proportional uptake of Sr 89 in relation to Ca by plants growing in different types of peat soils was found to decrease with increasing degree of decomposition, i.e. with decreasing C/N ratio, and with increasing humic acid content and CEC (meq/l) of the growth medium.

Increasing amounts of various fractions of organic matter (humin, and humic acids) mixed with a finesand decreased the uptake of radiostrontium and calcium by plants. However, the Sr 89/Ca ratio of the plants increased when the organic matter content of the soil was low.

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SELOSTUS

Maaperätekijöiden vaikutus kasvien radiostrontiumin ottoon. III

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Aikaisemmat tulokset osoittivat, että turpeen lisäys humusköyhään kivennäismaahan alensi voimakkaasti kasvien Sr 89/Ca-suhdetta. Tässä tutkimuksessa on pyritty selvittämään, mitkä ovat ne turpeen ominaisuudet, jotka vaikuttavat kasvin radiostrontiumin ottoon.

Astiakokeissa tutkittiin sekä turpeen maatumisasteen että turpeesta kemiallisesti erotettujen humushappojen ja humiinin vaikutusta kauran Sr 89/Ca -suhteeseen. Taulukossa 1 on esitetty astiakokeissa käytetyn orgaanisen aineksen ominaisuudet.

Maatumisen vaikutusta selvitettäessä valittiin koemaiksi neljä maatumisasteeltaan erilaista turvemaata, jotka olivat tyypiltään rahka-, sara- ja puusaraturvetta, lisäksi yhtenä koemaana oli kuorihumus, joka on kompostoitua havupuun kuorintajätettä. Ilmeni, että turpeen maatumisasteen kasvaessa kasvien Sr 89/Ca -suhde aleni (kuva 1). Turpeen maatuneisuuden lisääntyessä mm. sen hiili/typpi -suhde pieneni, ja kationinvaihtokapasiteetti (me /l) ja humushappopitoisuus kasvoivat (kuva 2).

Lisättäessä humushappoja ja humiinia hienoon hiekkaan kasvien radiostrontiumin ja kalsiumin otto aleni voimakkaasti (kuva 3). Kalsiumin otto aleni kuitenkin voimakkaammin kuin radiostrontiumin, joten kasvien Sr 89/Ca -suhde kasvoi (kuva 4) ja alkoi alentua vasta maan hiilipitoisuuden ollessa suurin. Humiinin ja humushappojen vaikutus kasvien Sr 89/Ca -suhteeseen oli erilainen kuin turpeen. Tämä voi johtua humiini- ja humushappomaiden pH-arvojen suuresta vaihtelusta tai kemiallisen käsittelyn aiheuttamista aineen ominaisuuksien muutoksista.

ANNALES AGRICULTURAE FENNIAE, VOL. 10: 131—134 (1971)
Seria ANIMALIA NOCENTIA N. 54 — Sarja TUHOELÄIMET n:o 54

EFFECTIVENESS OF DIMETHOATE, FORMOTHION AND METHYL PARATHION AGAINST LYGUS RUGULIPENNIS POPP. AT DIFFERENT TEMPERATURES

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Received 3 November 1970

The Mirid bug *Lygus rugulipennis* Popp. often causes injury to young sugar beet plants in Finland (VARIS 1959). Several insecticides have proved effective against this pest in laboratory conditions, but in the field control is often poor. The toxicity of certain insecticides has been reported by several authors (e.g. GAINES and DEAN 1949, MISTRIC and GAINES 1953, MISTRIC and MARTIN 1956) to be influenced by climatic factors, especially temperature. In 1967 and 1968, studies were conducted at Tikkurila on the effectiveness of dimethoate, formothion and methyl parathion against *Lygus rugulipennis* at different temperatures.

Material and methods

Experiments were conducted in four ambient temperatures, +5°C, +10°C, +15°C and +20°C, in mixed light of fluorescent and incandescent lamps in constant temperature cabinets, 1.6 m^3 each.

Seedling sugar beet plants growing in pots Ø 15 cm were treated with insecticides and kept at room temperature till the following day. Then a PVC rearing cage containing 10 untreated *Lygus rugulipennis* adults was placed over each pot, and the pots were moved to constant-temperature cabinets. The bugs had been netted from spring wheat at Tikkurila. They were kept in rearing cages for at least one night before the start of the experiment so that any individuals hurt during capture could be eliminated.

The treatments were

1. Methyl parathion dust, a.i. 22.5 mg/m^2
2. Dimethoate spray, a.i. 32.0 mg/m^2
3. Formothion spray, a.i. 40.0 mg/m^2
5. Untreated

Four replicates of each treatment were set up and the experiment was repeated twice. It was begun on Aug. 22, 1967, and repeated on September 5, 1967, and Aug. 27, 1968. The total number of bugs per treatment was 480, with males and females in equal numbers. Survival records were made and the damage to the plants was checked three days after treatment. Percentage control was calculated by Abbott's formula.

Results

The percentage control calculated on the basis of surviving bugs was lowest at 5°C and better the higher the temperature in the range +5°C—+20°C (Table 1).

The highest percentage control was obtained with methyl parathion treatment. Both dimethoate and formothion were significantly less

Table 1. Percentage control of *Lygus rugulipennis* at different temperatures, calculated on the basis of surviving bugs.
Taulukko 1. Elävien yksilöiden perusteella laskettu teho Lygus rugulipennikseen eri lämpötiloissa.

Treatment *Käsittely*	Temperature°C *Lämpötila*				Mean *Keskiarvo*
	5	10	15	20	
Methyl parathion — *Metyyliparationi*	48	62	74	82	66
Dimethoate — *Dimetoaatti*	24	42	56	45	42
Formothion — *Formotioni*	22	41	50	60	43
Mean — *Keskiarvo*	31	48	60	62	

Treatments F — *Käsittelyt* 20.4** LSD at 5 % 9
Temperatures F — *Lämpötilat* 16.3** LSD at 5 % 10
Treatments × temperatures F
Käsittelyt × lämpötilat 0.8°

Table 2. Percentage control of *Lygus rugulipennis* at different temperatures calculated on the basis of plant injury.
Taulukko 2. Kasvien vioittumisen perusteella laskettu teho Lygus rugulipennikseen eri lämpötiloissa.

Treatment *Käsittely*	Temperature°C *Lämpötila*				Mean *Keskiarvo*
	5	10	15	20	
Methyl parathion — *Metyyliparationi*	36	49	54	67	52
Dimethoate — *Dimetoaatti*	2	42	46	52	36
Formothion — *Formotioni*	—11	26	37	53	26
Mean — *Keskiarvo*	9	39	46	57	

Treatments F — *Käsittelyt* 12.0** LSD at 5 % 10
Temperatures F — *Lämpötilat* 27.7** LSD at 5 % 12
Treatments × temperatures F
Käsittelyt × lämpötilat 1.3°

effective, the difference between them not being significant.

In all treatments, considerable injury was caused to the plants by the bugs. The damage was least in the methyl parathion treatment. In the dimethoate treatment the plants were somewhat more severely damaged. The plants treated with formothion suffered the most severe damage, but even so, considerably less than the untreated ones. The treated plants suffered least at 20°C, the untreated ones at 5°C (Fig. 1)

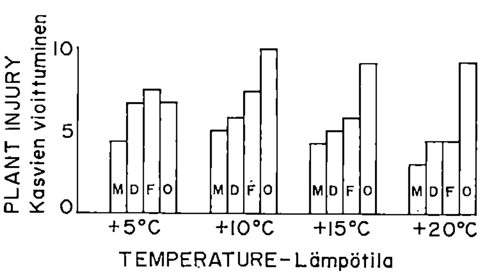

Fig. 1. The injury to sugar beet plants caused by *Lygus rugulipennis* at different temperatures and treatments. Scale 0—10 (uninjured-totally destroyed)
Kuva 1. Lygus rugulipenniksen aiheuttama sokerijuurikkaan taimien vioittuminen käsittelyittäin ja lämpötiloittain. Asteikko 0—10 (vioittumaton—täysin tuhottu)

M = Methyl parathion — *Metyyliparationi*
D = Dimethoate — *Dimetoaatti*
F = Formothion — *Formotioni*
0 = Untreated — *Käsittelemätön*

Table 2 shows the percentage control calculated on the basis of plant injury. It was very poor at 5°C and better the higher the temperature. The highest percentage control was obtained with methyl parathion treatment.

Discussion

The efficiency of the treatments was especially poor at cool temperatures. In was better the higher the temperature in the range +5°C—+20°C. In the laboratory experiments of Mistric and Martin (1956) on the effect of weather conditions on the toxicity of parathion, etc., when used to control the cotton aphid, the temperatures were higher, the lowest temperature approximately corresponding to the highest in the present study. The cotton aphid was more effectively controlled at medium temperature (+94°F = +34°C) than at either low (+70°F = +21°C) or high (+107°F = +42°C) temperatures. These records were based on the number of survivors.

In the present study the percentage control calculated on the basis of plant injury was considerably poorer than that based on surviving bugs. The difference between the two values was least in the dimethoate treatment.

It was not possible to continue the experiment further, because of the rather severe damage to the plants, which would soon have led to higher mortality of the bugs. Thus the final mortality caused by the treatments cannot be seen from the results. It is obvious, however, that if the effectiveness of the treatments is either poor or slow, the small seedlings are injured in spite of the treatment.

In field conditions the effectiveness of the treatment will be reduced by migration of bugs from surrounding fields. Moreover, rain will also reduce its effectiveness (cf. MISTRIC and MARTIN 1956). In the present study, only the soil was watered.

Summary

The effectiveness of dimethoate, formothion and methyl parathion against *Lygus rugulipennis* in four ambient temperatures, +5°C, +10°C, +15°C and +20°C, was studied at Tikkurila. Methyl parathion was applied as dust a.i. 22.5 mg/m², dimethoate a.i. 32.0 mg/m² and formothion a.i. 40.0 mg/m² as sprays to sugar beet seedlings. Untreated bugs were transferred to the plants on the day following treatment, the number of males and females being equal in each treatment. Survival records were made and the injury to the plants checked three days after treatment.

The percentage control, calculated on the basis of surviving bugs, was lowest at 5°C and better the higher the temperature in the range +5°C — +20°C (Table 1). The highest percentage control was obtained with methyl parathion treatment. Both dimethoate and formothion were significantly less effective, the difference between them not being significant.

The injury to plants caused by the bugs was considerable in all treatments. The treated plants suffered least at 20°C, the untreated ones at 5°C.

Percentage control calculated on the basis of plant injury was poorer than that based on surviving bugs. The difference was slight in the dimethoate treatment. Percentage control calculated on the basis of plant injury was very poor at 5°C and improved at higher temperatures (Table 2). The highest percentage control with the amounts of insecticide applied was obtained with methyl parathion treatment.

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SELOSTUS

Dimetoaatin, formotionin ja metyyliparationin teho peltoluteeseen eri lämpötiloissa

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Ruukuissa kasvavat sokerijuurikkaan sirkkataimet käsiteltiin torjunta-aineilla. 40 %:n dimetoaattiruiskutetta käytettiin 0.1 %:n laimennoksena 800 l/ha vastaava määrä, 25 %:n formotioniruiskutetta 0.2 %:n laimennoksena samoin 800 l/ha ja 1.5 %:n metyyliparationipölytettä 15 kg/ha vastaava määrä. Luteet pantiin taimille käsittelyn jälkeisenä päivänä, ja ruukut siirrettiin kasvatuskaappeihin +5°C:n, +10°C:n, +15°C:n ja +20°C:n lämpötiloihin. Luteiden kuolleisuus ja taimien vioittuminen tarkastettiin kolmen vuorokauden kuluttua käsittelystä.

Koiraita ja naaraita oli jokaisessa koejäsenessä yhtä paljon.

Luteiden kuolleisuus oli kaikissa käsittelyissä korkeammissa lämpötiloissa suurempi kuin alemmissa. Elävien yksilöiden perusteella laskettu teho (taul. 1) oli alhaisin +5°C:ssa, ja se oli yleensä sitä parempi, mitä korkeampi lämpötila oli. Tutkittuja ainemääriä käytettäessä metyyliparationikäsittely tehosi parhaiten.

Luteiden aiheuttama vioitus oli käsittelemättömissä taimissa vähäisin alhaisimmassa lämpötilassa (kuva 1), jossa luteiden aktiivisuus oli vähäisintä. Käsitellyt taimet vioittuivat vähiten +20°C:ssa, tässä lämpötilassa aineet tehosivat parhaiten.

Luteiden aiheuttaman taimien vioittumisen perusteella laskettu teho jäi erittäin heikoksi viileässä ja oli sitä parempi, mitä korkeampi lämpötila oli (taul. 2).

Käsittelystä huolimatta taimet vioittuivat melko pahoin. Kentällä aineiden tehoa heikentävät vielä ympäristöstä pellolle siirtyvät luteet sekä mahdollisesti sateet. Kokeissa taimet kasteltiin ainoastaan kasvualustan kautta.

ANNALES AGRICULTURAE FENNIAE, VOL. 10: 135—143 (1971)

Seria AGROGEOLOGIA, -CHIMICA ET -PHYSICA N. 55
Sarja MAAPERÄ, LANNOITUS JA MUOKKAUS n:o 55

THE EFFECT OF SOME SOIL CHARACTERISTICS ON THE EXTRACTABILITY OF MACRONUTRIENTS

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Received 11 November 1970

Among the most important characteristics of Finnish arable soils are their low pH and high average contents of organic matter and clay. These are fundamental factors affecting the availability of soil nutrients to plants and their extractability with suitable reagents. Acid ammonium acetate (0.5 *N* CH_3COOH, 0.5 *N* CH_3COONH_4, pH 4.65) is used in routine soil-testing in Finland (Vuorinen and Mäkitie 1955).

Average soil pH(H_2O) values, determined during the period 1955—1960, varied from 4.8 to 5.7, depending on the soil type (Kurki 1963). On the basis of their organic matter content, the soils are divided into three groups: (1) Mineral soils, organic matter content less than 15 %. (2) Mould soils, organic matter content 15—40 %. (3) Peat soils, organic matter content more than 40 % (Aaltonen et al. 1949). According to the same soil classification, clay soils are those with a clay content of more than 30 %. Clay contents of up to 95 % are found among Finnish heavy clays.

Sorption and desorption of macronutrients in Finnish soils as functions of soil factors and various extractants have been investigated previously e.g. by Salminen (1931), Kivinen (1938), Salonen (1941), Keränen (1946), Heinonen (1956), Purokoski (1959), Kaila (1967), and also Kaila and Rytti (1968). The aim of this study was to gain a general picture of the extractability of soil calcium, magnesium, potassium and phosphorus with acid ammonium acetate in relation to important soil characteristics. In order to obtain the most graphic presentation, the results are given as moving averages instead of regression or multiple regression analyses. The use of a computer (IBM 1130) proved very valuable in this study.

Material and methods

The material consisted of 321 arable layer soil samples from various parts of Finland. The air-dried samples were ground to pass a 2 mm sieve and extracted for one hour with acid ammonium acetate in a volumetric ratio of 1 : 10. Calcium, magnesium, potassium, phosphorus and iron were analysed from this extract. Organic matter was determined by wet digestion with sulphuric acid and potassium dichromate, nitrogen by the Kjeldahl method, the clay content by the pipette method and the cation exchange capacity by Mehlich's method. The mechanical composition and characteristics of the soils are presented in Tables 1 and 2.

Results and discussion

Interrelations of soil characteristics

The important soil characteristics (organic matter content (C %), clay content, cation

Table 1. Mechanical composition of mineral soils.
Taulukko 1. Kivennäismaiden mekaaninen koostumus.

Soil type	n	% in fraction (mm)						
		<0.002	0.002—0.006	0.006—0.02	0.02—0.06	0.06—0.2	0.2—0.6	0.6—2.0
Coarse mineral soils	145	16.8	14.1	14.0	18.9	22.7	10.8	2.7
		1.0—37.4	0.2—45.2	0.9—31.5	0.6—81.8	1.0—61.5	0—58.4	0—38.6
Clay soils	78	52.3	14.5	11.1	9.4	7.0	3.9	1.8
		30.8—83.5	0.8—34.9	3.5—26.8	0.2—27.8	0.9—23.2	0.5—13.6	0—15.3
Mean	223	29.2	14.2	13.0	15.6	17.2	8.4	2.4

Table 2. Characteristics of the soils.
Taulukko 2. Maiden ominaisuuksia.

Soil type	n	C %	N %	CEC meq/100 g	pH
Coarse mineral soils	145	3.15	0.227	17.3	5.44
		0.82—8.00	0.029—0.496	2.5—47.5	4.2—6.7
Clay soils	78	3.88	0.304	28.6	5.51
		1.80—8.34	0.151—0.597	15.6—47.8	4.8—6.1
Organogenic soils	98	24.40	1.27	75.8	4.87
		8.70—51.4	0.423—2.99	25.0—123	4.2—5.6
All soils	321	9.82	0.565	37.9	5.28

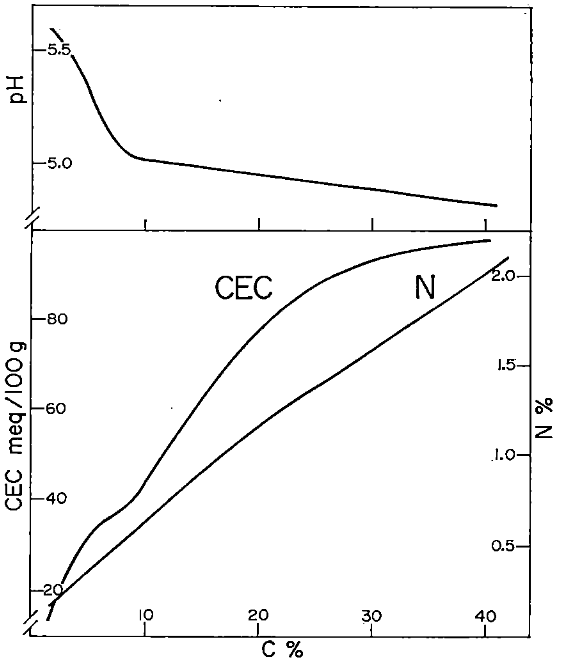

Fig. 1. Soil pH, CEC and N % as functions of soil C %.
Kuva 1. Maan pH, kationinvaihtokapasiteetti ja N % maan C %:n funktioina.

exchange capacity (CEC), soil pH) chosen for this study are already partially intercorrelated. A short examination of these relations is therefore necessary.

The relation between soil pH and organic matter content is as one would expect. There is a steep slope of the curve for soil pH down to pH 5.0 among the mineral soils (Fig. 1). The slight slope of the curve at a higher organic matter level is due to the higher buffering capacity. The turning point (C = 8—9 %) occurs close to mould, the first real organogenic soil.

Organic matter, together with soil clay content, primarily determines the cation exchange capacity. The great increase of CEC as a function of the first few C per cent is due to the fact that clay soils fall into this range (Table 2). Within the range of mould (C = 8.7—23.2 %) the increase of CEC is more linear up to peat soils, were there is a trend towards the constant value of CEC found in pure organic matter. The content of soil N % shows a linear increase up to C = 20 %. After this turning point, soil N % still increases linearly but a little more slowly.

Inspection of the results of the moving averages disclosed pronounced similarities between

Table 3. Distribution of samples according to organic matter content and clay content.
Taulukko 3. Näytteiden lukumäärä orgaanisen aineksen ja saven eri määrien luokissa.

Soil type	n	C %						Clay %							
		— 1.99	2.00— 3.99	4.00— 7.99	8.00—24.99	25.00—34.99	35.00—	— 4.9	5.0— 9.9	10.0—14.9	15.0—19.9	20.0—24.9	25.0—29.9	30.0—34.9	35.0—
Sand	7	5	1	1				2	2	1		2			
Finesand	76	15	47	11	3			24	30	8	4	7	3		
Loam	30	1	24	5						1	3	10	16		
Silt	32		29	3						2	1	1	12	13	3
Sandy clay	33		23	9	1									8	25
Silty clay	26		14	11	1									3	23
Heavy clay	19	1	9	9											19
Mould	41				41										
Carex peat	51					31	20								
Sphagnum peat	6					3	3								

the slopes of the curves of CEC and C % as functions of soil clay content (Fig. 2). Soil CEC increases linearly with soil clay content in soils containing more than 30 % of clay. At lower clay levels, soil CEC varies arbitrarily with clay content but follows soil organic matter content very closely. The organic matter content (C % = 3.15) of coarse mineral soils is responsible for most of the CEC of these soils. This is in agreement with the results of HEINONEN (1960) as well as ERVIÖ and MÄKITIE (1969), who studied the respective contributions of the mineral fraction and organic matter content to the CEC of Finnish soils.

Organic matter content

Examination of the extractability of macronutrients as functions of soil organic matter content (Fig. 3) shows that soil type should also be taken into consideration. There are pronounced maxima in the extractability of potassium and of magnesium and a smaller peak in that of calcium at the C % level 4—5. The maxima are caused by the high contents of K, Mg and Ca in the clay soils, which are concentrated at this level of soil organic matter content (Tables 2 and 3). Another maximum of magnesium coincides with an increase in phosphorus content around C = 30 %. This is caused by a great number of Carex peat samples naturally rich in nutrients.

The amount of readily soluble phosphorus is rapidly halved at the organic matter level at which potassium, magnesium and calcium approach a maximum. The phenomenon is partly explained by the increasing clay content. In spite of the rather high nutrient reserves of clays, the extractability of readily soluble phosphates remains low, owing to the high affinity of clays for anions. Another and obviously more important factor causing a sudden decrease in the extractability of phosphorus is the correspondingly rapid increase in the extractability of iron as a function of soil organic matter, which was found in another study (LAKANEN and HYVÄRINEN 1971).

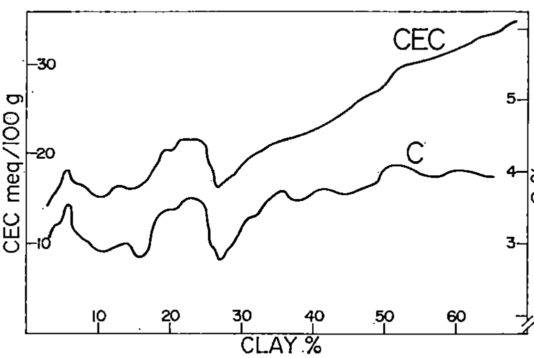

Fig. 2. CEC and C % as functions of clay content.
Kuva 2. Kationinvaihtokapasiteetti ja C % savipitoisuuden funktioina.

Since iron is such an important factor in the fixation of phosphorus in acid soils, the extractability of phosphorus with acid ammonium acetate is plotted against that of iron in Fig. 4. The amount of readily soluble phosphorus falls rapidly towards 10 mg/l of soil at the iron content of 18 mg/l of soil, which gives the Fe/P equivalent ratio of ferric phosphate. Beyond this turning point, any excess of trivalent iron lowers the amount of phosphorus still further, according to the solubility product of ferric phosphate, which is illustrated by the dissociation of strengite.

$$FePO_4 \cdot 2\,H_2O \rightleftharpoons Fe^{3+} + H_2PO_4^- + 2\,OH^-$$

Mäkitie (1966) has made a detailed study of the solubility of iron and aluminium phosphates in the acid ammonium acetate extractant. The results given in Fig. 4 are in agreement with these data and show clearly that, in acid soils in which iron phosphate predominates, there is a strict limit to the amount of acid ammonium acetate extractable phosphorus.

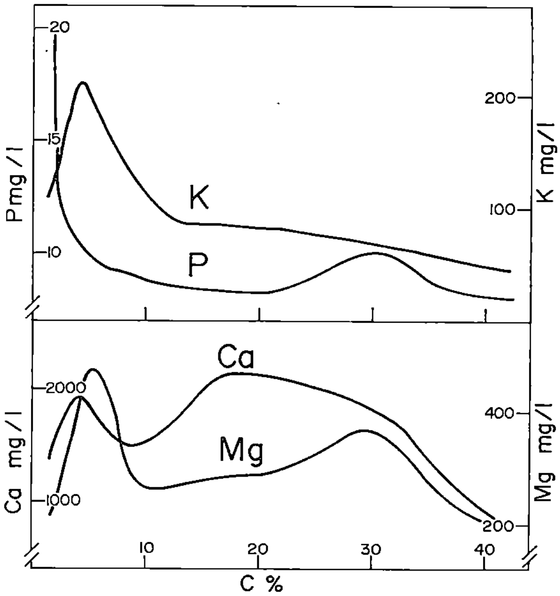

Fig. 3. The extractability of potassium, phosphorus, calcium and magnesium as functions of organic matter content.
Kuva 3. Kaliumin, fosforin, kalsiumin ja magnesiumin uuttuminen orgaanisen aineksen pitoisuuden funktioina.

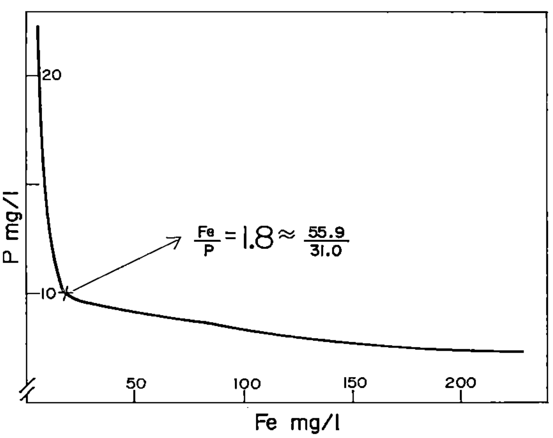

Fig. 4. The extractability of phosphorus as a function of soluble iron.
Kuva 4. Fosforin uuttuminen liukoisen raudan funktiona.

Clay content

The effect of the clay content on the extractability of nutrients (Fig. 5) is easily understood.

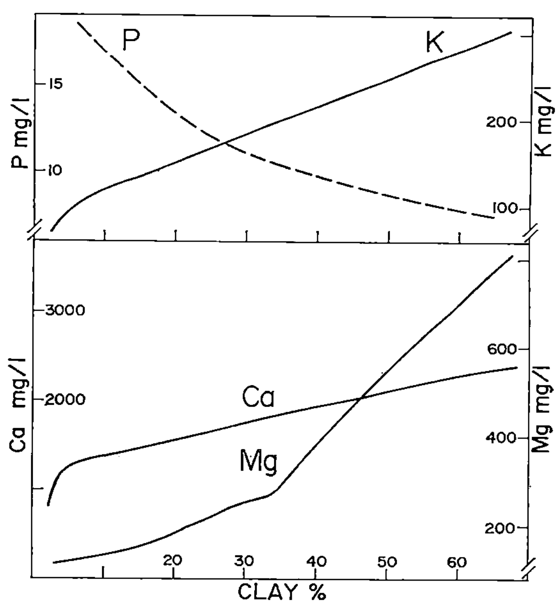

Fig. 5. The extractability of phosphorus, potassium, calcium and magnesium as functions of clay content.
Kuva 5. Fosforin, kaliumin, kalsiumin ja magnesiumin uuttuminen savipitoisuuden funktioina.

The increasing anion adsorption capacity due to increasing clay content results in a decrease of readily soluble soil phosphorus. Because of the scattering of the data, only the tendency of phosphorus behaviour is expressed as a dotted line. At the same time, however, the high natural contents of exchangeable potassium and magnesium in clays increase the extractability of these elements and also that of calcium, in spite of the levelling effect of liming on calcium content in various soils. The increase of magnesium content with increasing clay content becomes clearly visible at clay contents of over 35 %.

The mean clay content of mineral soils is 29.2 % and the mean silt content 27.2 %. Clay and silt together account for the greater part of the calculated relative surface area, figures for which are presented in Fig. 6. An increase in surface area results in increased extractability of potassium, magnesium and calcium. Thus, the extractability of calcium and magnesium increases more rapidly with relative surface area than with the percentage of the clay fraction alone. The steeper gradient of the surface area curves is caused by the silt fraction (0.002—0.02 mm). The high magnesium content of the clays and the increasing effect of silt on the potassium content are in agreement with the results obtained in previous Finnish investigations (Kaila and Ryti 1968, Kaila 1967).

Cation exchange capacity

Cation exchange capacity is caused mainly by soil organic matter and clay. Organic matter, however, plays the more important role, as is also seen from the similarities between Figs. 3 and 7, where the extractabilities of macronutrients are plotted as functions of organic matter content and CEC, respectively. At a low CEC level the amounts of extractable potassium, calcium and magnesium are small, because sand and finesand, naturally poor in exchangeable cations, are at the beginning of the curve (Table 4). The amounts of exchangeable cations increase rapidly towards a maximum that apparently consists of two parts. The maximum is caused by

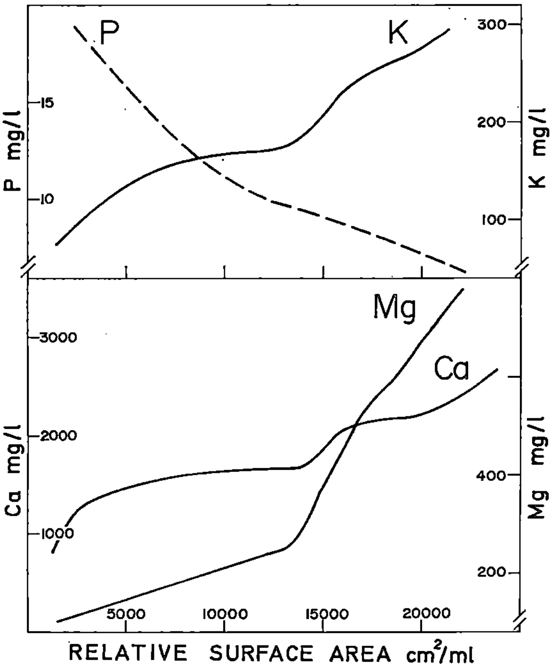

Fig. 6. The extractability of phosphorus, potassium, calcium and magnesium as functions of relative particle surface area.
Kuva 6. Fosforin, kaliumin, kalsiumin ja magnesiumin uuttuminen partikkelien suhteellisen pinta-alan funktioina.

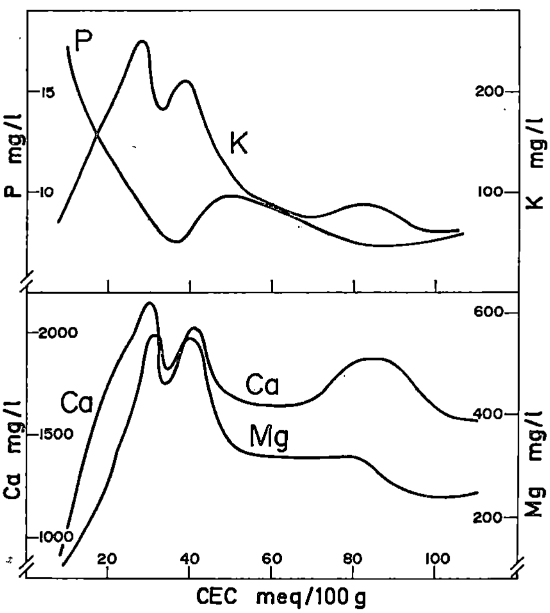

Fig. 7. The extractability of potassium, phosphorus, calcium and magnesium as functions of CEC.
Kuva 7. Kaliumin, fosforin, kalsiumin ja magnesiumin uuttuminen kationinvaihtokapasiteetin funktioina.

Table 4. Distribution of samples according to pH and CEC
Taulukko 4. Näytteiden lukumäärä eri pH- ja vaihtokapasiteetin luokissa

Soil type	n	pH							CEC meq/100 g							
		4.2—4.8	4.9—5.1	5.2—5.3	5.4—5.5	5.6—5.7	5.8—5.9	6.0—6.7	—9.9	10.0—19.9	20.0—29.9	30.0—39.9	40.0—49.9	50.0—69.9	70.0—99.9	100.0—
Sand	7	2	1	1	1	1		1	3	3	1					
Finesand	76	4	12	18	15	10	5	12	10	49	13	3	1			
Loam	30	2	2	7	6	7	4	2		19	7	4				
Silt	32		4	12	10	2	2	2		24	8					
Sandy clay	33		3	12	8	5	4	1		8	17	8				
Silty clay	26	1	1	3	8	6	3	4		5	14	6	1			
Heavy clay	19			4	9	2	3	1			2	12	5			
Mould	41	11	18	11		1					3	3	9	14	11	1
Carex peat	51	27	14	5	3	2						2	3	4	26	16
Sphagnum peat	6	6													4	2

clay soils naturally rich in potassium, magnesium and calcium. Examination of single samples brought out five finesands rich in humus and CEC but low in exchangeable cations. The small but distinct downward dip in the maximum of exchangeable cations is probably caused by these five samples. Carex peats are naturally rich in calcium, for which reason another maximum of exchangeable calcium around a CEC of 80 meq/100 g is to be expected (Table 4).

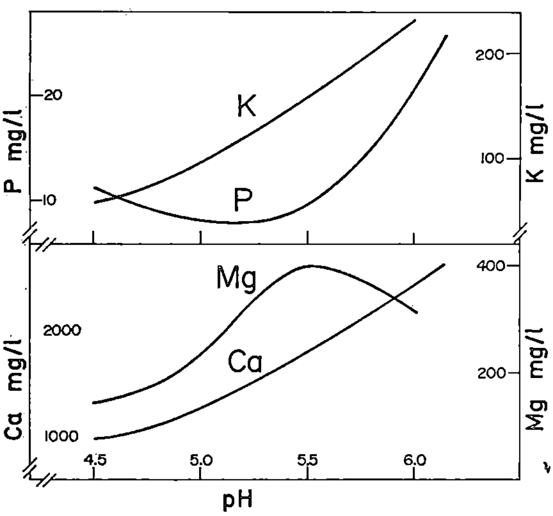

Fig. 8. The extractability of potassium, phosphorus, magnesium and calcium as functions of pH.
Kuva 8. Kaliumin, fosforin, magnesiumin ja kalsiumin uvttuminen pH:n funktioina.

Fertilizer phosphorus is readily extractable from coarse mineral soils low in CEC and clay, representing low anion-binding power. The highest extractability of readily soluble phosphorus occurs, therefore, at the lowest CEC levels. An increase of CEC leads to the range of clay soils, where there is a pronounced decrease in the extractability of soluble phosphorus, despite high level of exchangeable potassium, calcium and magnesium. Another factor obviously resulting in lowered extractability of phosphorus as a function of CEC is the simultaneous increase of extractable soil iron. This increase is due to the increasing soil organic matter content.

Soil pH

The relations between soil pH and acid ammonium acetate extractable calcium, potassium and phosphorus in various Finnish soils are presented in detail in another study consisting of about 80 000 soil tests (Lakanen et al. 1970). The present material (321 samples) does not, of course, give such an accurate picture. The results (Fig. 8), however, are in agreement with those of the previous study. The most important observations are those concerning the behaviour of readily soluble phosphorus. Liming of acid Finnish soils raises the pH. As the pH approaches the value 5.5, a slight minimum of

Table 5. Distribution of samples according to magnesium content and iron content
Taulukko 5. Näytteiden lukumäärä magnesiumin ja raudan eri määrien luokissa

Soil type	n	Mg mg/l of soil						Fe mg/l of soil						
		— 99	100—199	200—299	300—499	500—699	700—	— 9.9	10.0—19.9	20.0—39.9	40.0—79.9	80.0—159.9	160.0—199.9	200.0—
Sand	7	4	2		1			5		1		1		
Finesand	76	28	27	14	3	4		17	17	17	13	6	3	3
Loam	30	6	13	7	4			11	9	2	3	2	2	1
Silt	32	1	17	11	2	1		13	12	3	3	1		
Sandy clay	33		1	6	12	7	7	4	4	10	9	4	1	1
Silty clay	26		3	6	2	10	5	1	11	5	5	1	2	1
Heavy clay	19					5	14		3	5	4	6	1	
Mould	41	7	9	10	6	7	2		1	3	5	15	8	9
Carex peat	51	10	17	6	10	7	1	1		1	6	12	12	19
Sphagnum peat	6	3	1			2		1		2	2	1		

soluble phosphorus occurs, followed by a rapid rise after pH 6. The same phenomenon has also been observed in a pot experiment (Lakanen and Vuorinen 1963). It seems that the solubility minimum occurs mainly in organogenic soils. According to Puustjärvi (1956), the readily soluble phosphorus fell by almost half when a peat soil was limed from pH 5.05 to 5.85. Anttinen (1959) reported results of a long-term trial in which liming of Carex peat from 5.0 to 5.4 significantly decreased the yield of a crop of oats. A decrease of acid ammonium acetate extractable soil phosphorus occurred simultaneously. This detrimental effect of liming of acid organogenic soils requires thorough investigation.

In mineral soils the amount of exchangeable magnesium increases with decreasing particle size. The maximum content of magnesium occurs near pH 5.5, around which the majority of the heavy clays rich in magnesium are gathered (Tables 4 and 5).

Summary

Values for the extractability of calcium, magnesium, potassium and phosphorus with acid ammonium acetate from 321 Finnish soils are presented as functions of organic matter content, clay content, CEC and pH. The results, presented graphically as moving averages, are discussed.

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SELOSTUS

Maaperän ominaisuuksien vaikutuksesta pääravinteiden uuttumiseen

ESKO LAKANEN ja SEPPO HYVÄRINEN

Maatalouden tutkimuskeskus, Maantutkimuslaitos, Tikkurila

Suomalaisille maille tyypillisiä ominaisuuksia ovat alhainen pH, keskimääräisesti korkea humuspitoisuus ja saviaineksen runsaus, jotka kaikki vaikuttavat myös maan viljavuuteen. Laboratoriossa viljavuustutkimus suoritetaan uuttamalla maanäytteet happamalla ammoniumasetaatilla (pH 4.65) ja analysoimalla uutteiden ravinnepitoisuudet.

Tässä tutkimuksessa tarkastellaan eräiden maaperätekijöiden vaikutusta kalsiumin, magnesiumin, kaliumin ja fosforin uuttumiseen viljavuusanalyysin uuttonesteeseen. Kalkituksen ja lannoituksen eroja tasaavasta vaikutuksesta huolimatta maaperätekijät säätelevät edelleen ravinteiden uuttumista ja niiden käyttökelpoisuutta kasveille. Mahdollisimman yksityiskohtaisen ja havainnollisen kuvan saamiseksi alkuperäisaineisto käsiteltiin liukuvin keskiarvoin, ja tulokset esitetään kuvissa 1—8. Runsaasti aikaa vaativaan 25—50 kappaleen liukuvien keskiarvojen laskemiseen osoittautui tietokonekäsittely tehokkaaksi. Eri puolilta Suomea olevan 321 maanäytettä käsittävän aineiston mekaaninen koostumus ja muita ominaisuuksia esitetään taulukoissa 1—5.

Ravinteiden uuttumiseen vaikuttavat maaperätekijät ovat myös keskinäisissä riippuvuussuhteissa. Humuspitoisuuden kasvaessa pH alenee aluksi voimakkaasti kivennäismaiden alueella C = 8—9 % saakka (kuva 1). Tästä alkavalla multamaan ja turpeiden alueella on pH:n lasku humuksen suuren puskurikapasiteetin johdosta vähäistä. Orgaanisen aineksen kasvu lisää voimakkaasti kationinvaihtokapasiteettia (CEC kuvassa 1). Käyrän alkuosan jyrkkä nousu johtuu savien kerääntymisestä C = 4 % paikeille. Sitä seuraava vaihtokapasiteetin suoraviivaisempi kuvaajan osa on multamaan aluetta, kunnes tullaan turvemaiden alueelle sekä yhä lähemmäksi puhdasta orgaanista ainetta ja vaihtokapasiteetin vakiotasoa. N % seuraa C %:a suoraviivaisesti koko ajan — tosin C % = 20 jälkeen loivemmassa kulmassa. Savimaissa (savipitoisuus > 30 %) kasvaa kationinvaihtokapasiteetti lineaarisesti savipitoisuuden mukana (kuva 2). Samaan kuvaan piirretty C %:n vaihtelu on mielivaltaista, mutta vaihtokapasiteetti seuraa sitä alle 30 %:n savipitoisuuksissa yksityiskohtaisesti, mikä osoittaa näiden kivennäismaiden humuspitoisuuden vielä selvästi säätelevän kationinvaihtokapasiteetin arvoa.

Humuspitoisuuden kasvaessa käyvät kaliumin ja magnesiumin määrät maksimissa C = 4—5 % paikkeilla, mitä myötäilee myös vaihtuvan kalsiumin määrä (kuva 3). Runsaat pitoisuudet eivät ole kuitenkaan humuksen, vaan tälle alueelle kertyneiden ravinnerikkaiden savien aiheuttamia. Magnesiumin ja fosforin uuttumisen lisääntyminen C = 30 % läheisyydessä osoittautui puolestaan saraturpeiden ravinnerunsaudesta johtuvaksi. Humuspitoisuuden kasvaessa kaliumin ja magnesiumin suuria pitoisuuksia edustavalle savien alueelle on maan helppoliukoinen fosfori pudonnut jyrkästi savien suuren anionien pidätysvoiman johdosta. Tärkeämpi tekijä lienee kuitenkin humuspitoisuuden kasvun aiheuttama uuttuvan raudan määrän nopea lisääntyminen, jolloin pian saavutetaan ferrifosfaatin muodostumiseen riittävä rautamäärä. Helppoliukoisten fosfaattien määrä pysähtyy tällöin lähes vakiotasolle (kuva 4).

Savipitoisuuden vaikutus lisää odotetusti vaihtuvan kaliumin ja kalsiumin määriä. Selvimmin saven vaikutus ilmenee uuttuvan magnesiumin voimakkaassa kasvussa. Lisääntyvä anionien sitomisvoima näkyy uuttuvan fosfaattifraktion pienenemisenä (kuva 5). Aineiston kivennäismaiden savipitoisuuden keskiarvo on 29.2 % ja hiesufraktioiden 27.2 %. Nämä hienoimmat lajitteet määräävät lähes täysin maahiukkasten suhteellisen lasketun pinta-alan, jonka vaikutusta pääravinteiden uuttumiseen esittää kuva 6. Pinta-alan kasvu — so. hiukkaskoon pieneneminen — lisää vaihtuvien kationien määrää. Hienon ja karkean hiesun vaikutuksen huomioon ottaminen on lisännyt vaihtuvan kaliumin ja kalsiumin määrää voimakkaammin kuin pelkkä savifraktio kuvassa 5.

Kationinvaihtokapasiteetti muodostuu pääasiallisesti humuksesta ja savesta. Eloperäisen aineksen suurta osuutta kuvastaa humuspitoisuuden ja vaihtokapasiteetin samanlainen vaikutus ravinteiden uuttumiseen (kuvat 3 ja 7). Jälkimmäinen kuitenkin antaa tapahtumasta yksityiskohtaisemman kuvan, kuten maan partikkelikoon suhteellinen pinta-ala antoi pelkkään savifraktioon verrattaessa.

Happamien maiden kalkituksen odotetaan lisäävän helppoliukoisten fosfaattien määrää. Seurauksena saattaa kuitenkin olla kuvassa 8 esitetty liukoisuuden lievä aleneminen pH 5.5:ä lähestyttäessä, mikä on todettu aikaisemminkin. Tämän haitallisen ilmiön syiden selvittäminen edellyttää lisätutkimuksia.

Maaperän tärkeiden ominaisuuksien huomioon ottaminen yksitellen ei riittävästi selitä ravinteiden uuttumista. On otettava huomioon myös tekijöiden yhteisvaikutus, maalaji ja muita tärkeitä ympäristötekijöitä.

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WEED SEEDS IN CULTIVATED SOILS IN FINLAND

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There have been several previous studies on the distribution and abundance of farmland weeds in Finland (KUJALA 1934, PAATELA 1953, RAATIKAINEN and RAATIKAINEN 1964, MUKULA et al. 1969). In spring cereal fields not subjected to weed control measures the average number of growing weeds has been found to be 550 plants/m^2 (MUKULA et al. 1969). Most of these distribute seeds in varying amounts, depending on the density of the weed stand. According to WEHSARG (1954), weeds in cereal fields produce the following numbers of seeds: *Raphanus raphanistrum* 200—300, *Lapsana communis* and *Thlaspi arvense* 400—800, *Stellaria media* and *Capsella bursa-pastoris* 1 000—1 500 seeds per plant. OVERGAARD (1919—22) reports an average shedding of 14 000 seeds per m^2 (ranging from 84 to 91 736). Weed seeds are able to maintain their viability and persist in soils for years, or even decades. According to KORSMO (1954), seeds of *Sinapis arvensis* still germinated after a 34-year ley. KUJALA (1934) reports that seeds of *Viola arvensis* and *Polygonum lapathifolium* maintained their viability in the soil for at least 40 years. DARLINGTON and STEINBAUER (1961) found that seeds of *Polygonum hydropiper* and *Brassica nigra* were still viable after 50 years and those of *Rumex crispus* after 80 years. Recent archaeological research has revealed that the longevity of weed seeds in soil may be even hundreds of years (ØDUM 1965).

Since no studies on weed seed populations present in Finnish arable soils had been published before, such a study was conducted at the Department of Plant Husbandry of the University of Helsinki in the 1960s. In the summer of 1964, soil samples from cultivated fields in the southern and central parts of the country were collected by the Department of Plant Husbandry, Agricultural Research Centre, Tikkurila, in connection with a countrywide survey (MUKULA et al. 1969). The latter institute also provided financial support for the investigation of the collected sample material from special funds allocated for this purpose. The samples were investigated for their contents of weed seeds at the University Department of Plant Husbandry in 1964—67.

Sample material

The soil samples were collected from fields of spring cereals in southern and central Finland. The number of sampling districts was eight, each consisting of one to three rural communes selected to form a uniform area (Fig. 1).

Distribution of soil samples by soil type:

District	Coarse mineral soils	Fine mineral soils	Organic soils	Total no. of fields sampled
1	22	73	10	105
2	32	70	7	109
3	—	73	27	100
4	70	16	20	106

5	19	57	23	99
6	41	6	53	100
7	19	50	27	96
8	65	6	29	100
Total	268	351	196	815

In each district an average of 102 (96—109) soil samples were taken on farms representing the average local agricultural standard. Besides fields where no herbicides had been used, fields were accepted where the effect of preceding herbicidal treatment was not particularly strong (cf. Mukula et al. 1969). The soil samples were taken between 24 June and 16 July 1964 from the same plots on which the weed counts for the above-mentioned survey were made, from the cultivated layer of the soil. Eight soil cores (6 cm² in area, 20 cm deep) were taken from each field; these were mixed together and 600 cm³ of the combined sample kept for analyses.

Treatment of sample material

The soil samples were stored at +2—+4°C. Analysis was carried out by a method developed at the University Department of Plant Husbandry, closely resembling that used by Kropac (1966). The soil was washed through four sieves of different mesh sizes, placed on top of each other, which retained the weed seeds. The bottom mesh was close enough not to let even the smallest seeds pass through. The material accumulated on the sieves was then collected and dried. The organic matter was separated from the inorganic by immersing the sample in 1.6—1.8 g/ml NaCl solution in a glass cylinder. As soon as the inorganic matter had settled, the supernatant was decanted on to filter paper and dried. From this, weed seeds were separated partly by hand, partly by sifting. A total of 107 249 seeds were found in the 815 samples, which gives an average of 132 seeds per sample and corresponds to 44 000 seeds/m² in a 20-cm surface layer of cultivated soil. After identification by species or genera, frequencies and abundances were calculated for these by sampling districts and soil types.

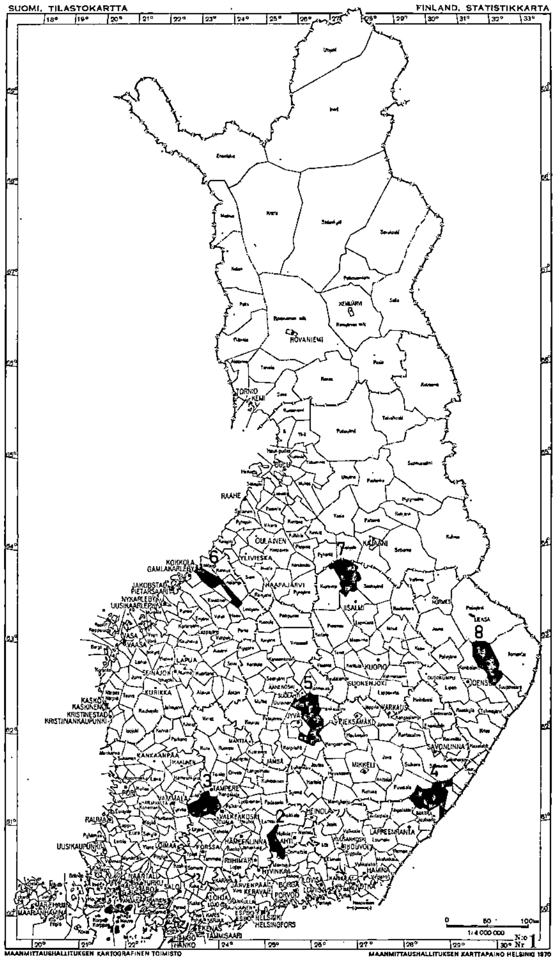

Fig. 1. Sampling districts 1—8 and the rural communes selected for the study: 1 = Korppoo—Nauvo, 2 = Koski H.l.—Kärkölä, 3 = Lempäälä—Pirkkala—Vesilahti, 4 = Ruokolahti—Taivalkoski, 5 = Laukaa—Toivakka—Lievestuore, 6 = Kälviä, 7 = Vieremä, 8 = Eno.

Results

Frequency

The most frequent species were (Table 1) *Chenopodium album* (91 %), *Brassica* spp. (89), *Spergula arvensis* (81), *Ranunculus* spp. (79), *Galeopsis* spp. (70), *Viola arvensis* (63) and *Stellaria media* (62). Twenty-one species or genera occurred in at least 10 %, and thirty-four in at least 3 % of the samples. Among the group »others» there were 7 species that occurred at

Table 1. Frequency of weed seeds (%) in south and central Finnish arable soils.

Weed species	District								Soil type			
	1	2	3	4	5	6	7	8	Coarse mineral soils	Fine mineral soils	Organic soils	Whole material
Chenopodium album	97	93	96	92	89	93	73	94	96	93	82	91
Brassica spp.	62	95	93	89	94	90	97	97	92	87	91	89
Spergula arvensis	86	88	85	81	74	81	67	81	87	80	73	81
Ranunculus spp.	50	75	75	91	83	94	71	94	84	74	82	79
Galeopsis spp.	45	79	65	87	80	76	48	82	82*	64	66	70
Viola arvensis	80	47	86	50	52	58	28	73	66	70	47**	63
Stellaria media	65	51	76	46	69	66	50	69	59	69*	52	62
Polygonum aviculare	59	42	42	49	53	51	28	52	54	49	34**	47
Myosotis arvensis	44	43	55	48	54	38	29	60	59	49	25***	46
Polygonum convolvulus	63	29	62	63	35	40	18	51	59	44	29***	45
P. lapathifolium	45	51	20	76	36	58	23	48	57	34***	50	45
Rumex acetosella	50	29	13	55	40	75	42	60	65	28***	49	45
Carex spp.	31	36	20	57	43	51	52	43	41	36	53*	42
Galium spp.	20	14	41	30	27	18	8	31	28	22	20	24
Alchemilla vulgaris	15	12	16	50	21	7	26	36	26	21	21	23
Lapsana communis	20	25	25	30	24	3	2	11	16	25***	8	18
Taraxacum vulgare	14	8	26	13	12	3	3	26	15	15	7*	13
Thlaspi arvense	12	5	33	9	12	18	7	10	16	14	9	13
Rumex aeetosa	9	16	13	9	6	15	8	19	14	10	13	12
Anthoxanthum odoratum	8	1	—	14	2	6	5	42	17	3***	12	10
Rumex domesticus	15	4	26	1	2	17	—	13	8	11	10	10
Polygonum hydropiper	8	6	3	14	5	5	9	9	7	6	11	7
Vicia spp.	4	2	10	13	7	7	3	2	5	7	7	6
Pedicularis palustris	6	—	9	2	6	6	3	13	7	4	6	6
Alopecurus geniculatus	4	4	4	9	9	9	4	1	4	6	6	5
Scleranthus annuus	12	5	13	4	3	2	—	—	6	7	—***	5
Trifolium spp.	1	7	4	4	3	1	7	—	3	4	3	3
Raphanus raphanistrum	1	2	2	9	4	6	2	1	4	3	3	3
Erysimum cheiranthoides	—	6	5	1	5	2	3	3	4	4	1	3
Lamium spp.	10	1	10	—	2	—	2	1	+**	4	6	3
Leontodon autumnalis	2	3	3	3	4	3	5	2	4	2	4	3
Potentilla spp.	1	3	1	4	2	2	1	10	5	1**	4	3
Matricaria inodora	4	1	8	—	1	8	1	1	2	3	4	3
Cirsium spp.	4	3	7	3	—	1	—	2	2	3	2	3
Others	38	23	36	24	25	45	36	26	27	28	43	32

least once in every 100 samples; among these were *Lathyrus pratensis*, *Centaurea cyanus*, *Prunella vulgaris*, *Phleum pratense* and *Anthriscus silvestris*.

Regional differences were found for several species. *Brassica*, *Ranunculus* and *Galeopsis* were less frequent in district 1 than elsewhere; *Lamium* spp. occurred more frequently in districts 1 and 3 than elsewhere. Seeds of *Alchemilla vulgaris* were usually found in samples from the eastern parts of the country (districts 4, 7 and 8) but rarely occurred in the west (district 6). *Galium* spp., *Rumex domesticus* and *Thlaspi arvense* were especially common in district 3 in comparison with the other areas. In the northernmost districts 6—8, seeds of *Lapsana communis* and *Scleranthus annuus* occurred less frequently than elsewhere.

Statistically significant differences due to soil type were found for 15 species (Table 1). Thus *Galeopsis* spp. were more frequent, *Lamium* spp. less frequent in coarse mineral soils than elsewhere. In clay soils, *Stellaria media* and *Lapsana communis* were more common, *Polygonum lapathifolium*, *Rumex acetosella* and *Potentilla* spp. rarer than in other soils. In peat, *Carex* spp. occurred more frequently, *Viola arvensis*, *Polygonum aviculare*, *P. concolvulus*, *Myosotis arvensis*, *Taraxacum vulgare* and *Scleranthus annuus* more rarely than in other types of soil.

Abundance

The most abundant species were (Table 2) *Chenopodium album* (10 020 seeds/m²), *Spergula*

Table 2. Abundance of weed seeds (no./m^2) in south and central Finnish arable soils.[1])

Weed species	District								Soil type			
	1	2	3	4	5	6	7	8	Coarse mineral soils	Fine mineral soils	Organic soils	Whole material
Chenopodium album	12 820^{bc}	6 390^{ab}	10 920^{bc}	10 320^{bc}	7 160^{ab}	13 050^{bc}	4 900^{a}	14 520^{c}	15 480	8 830	4 700	10 020
Spergula arvensis	18 220^{c}	11 620^{bc}	5 430^{a}	9 190^{abc}	6 330^{ab}	11 990^{bc}	5 990^{ab}	6 490^{ab}	11 120	6 960	11 790	9 490
Brassica spp.	1 510^{a}	6 770^{bc}	6 290^{bcd}	6 530^{bc}	5 230^{b}	4 960^{b}	9 530^{d}	8 690^{cd}	5 000	6 290	7 430	6 160
Stellaria media	4 600^{bc}	1 050^{a}	5 870^{c}	2 680^{b}	4 760^{bc}	7 250^{c}	3 240^{abc}	5 130^{bc}	5 190	4 370	2 950	4 300
Viola arvensis	3 430^{c}	2 390^{bc}	5 490^{d}	2 290^{bc}	2 050^{bc}	1 890^{b}	400^{a}	2 070^{b}	2 650	3 010	1 470	2 520
Ranunculus spp.	510^{a}	1 100^{b}	1 640^{bc}	3 400^{d}	1 830^{c}	4 020^{d}	1 620^{bc}	3 630^{d}	2 880	1 330	2 890	2 210
Galeopsis spp.	690^{a}	1 820^{bc}	860^{ab}	1 990^{c}	1 230^{b}	1 320^{b}	750^{ab}	1 520^{bc}	1 580	1 150	1 120	1 280
Carex spp.	770^{ab}	700^{ab}	360^{a}	2 070^{c}	770^{ab}	1 250^{bc}	1 170^{bc}	1 750^{abc}	820	750	2 160	1 110
Myosotis arvensis	540^{ab}	630^{ab}	820^{abc}	1 270^{abc}	1 650^{bc}	1 660^{abc}	310^{a}	1 520^{c}	1 580	810	750	1 050
Rumex acetosella	780^{c}	260^{b}	90^{a}	1 340^{c}	570^{bc}	2 430^{d}	660^{c}	840^{c}	1 470	330	1 020	870
Polygonum aviculare	1 150^{c}	390^{ab}	370^{ab}	850^{bc}	1 190^{bc}	1 190^{bc}	240^{a}	570^{b}	800	840	510	750
P. lapathifolium	1 150^{bc}	440^{b}	160^{ab}	1 460^{c}	420^{ab}	700^{b}	170^{a}	720^{b}	790	370	100	660
P. convolvulus	850^{b}	180^{a}	620^{b}	810^{b}	360^{ab}	620^{b}	140^{a}	760^{b}	810	490	280	540
Alchemilla vulgaris	170^{ab}	150^{ab}	230^{ab}	990^{b}	210^{ab}	60^{a}	440^{b}	910^{b}	580	330	260	400
Lapsana communis	400^{b}	290^{b}	270^{b}	880^{ab}	200^{b}	40^{a}	50^{a}	80^{a}	360	330	100	280
Thlaspi arvense	250	20	520	340	300	440	40	130	310	290	110	260
Galium spp.	110	50	610	250	190	230	40	220	180	220	220	210
Alopecurus geniculatus	100	30	40	70	340	600	90	10	190	90	240	160
Taraxacum vulgare	60	30	240	110	80	10	10	520	220	110	40	130
Rumex domesticus	230	30	360	+	20	200	—	160	80	110	210	120
Anthoxanthum odoratum	50	+	—	150	10	30	70	580	230	10	120	110
Rumex acetosa	40	100	80	110	20	100	70	120	90	60	110	80
Scleranthus annuus	220	70	260	80	20	10	—	—	90	120	—	80
Polygonum hydropiper	30	100	20	110	90	30	50	120	60	30	130	70
Vicia spp.	40	20	110	190	40	150	10	20	30	80	120	70
Matricaria inodora	40	50	130	—	30	100	+	10	20	60	50	50
Potentilla spp.	20	40	50	30	30	30	+	210	60	20	100	50
Pedicularis palustris	30	—	40	10	70	30	20	180	50	50	30	50
Erysimum cheiranthoides	—	70	20	10	20	10	150	20	40	50	10	40
Lamium spp.	90	+	220	—	10	—	10	+	+	40	100	40
Raphanus raphanistrum	+	10	10	70	10	30	10	+	30	10	10	20
Cirsium spp.	20	20	30	60	—	+	—	10	20	20	10	20
Trifolium spp.	+	20	20	20	10	+	40	—	20	20	10	20
Leontodon autumnalis	10	10	10	10	20	10	30	10	20	10	20	10
Others	450	200	310	420	250	2 350	640	400	310	300	1 610	620
Total	49 380	35 050	42 500	48 110	35 520	56 790	30 890	51 920	53 160	37 890	40 780	43 850

[1]) Values in the same column followed by the same letter do not differ from each other significantly at 95 % level.
Confidence limits between the sampling districts have been calculated for 15 most abundant species only.

Table 3. Effect of preceding crop upon the numbers of weed seeds in soil.

Weed species	Number of seeds/m²[1]				
	Spring cereals	Winter cereals	Ley	Potatoes and root crops	Significance x^2
Chenopodium album	10 770^{c}	9 570^{b}	6 880^{a}	19 670^{d}	***
Spergula arvensis	13 050^{d}	4 450^{b}	7 950^{c}	4 350^{a}	***
Brassica spp.	6 400^{b}	5 210^{a}	6 180^{b}	5 350^{a}	***
Stellaria media	4 740^{c}	2 940^{b}	2 110^{a}	10 130^{d}	***
Viola arvensis	2 870^{c}	2 350^{ab}	2 070^{a}	2 410^{abc}	*
Ranunculus spp.	2 250	1 890	2 290	2 150	
Galeopsis spp.	1 480^{b}	1 890^{bc}	970^{a}	2 030^{c}	***
Carex spp.	1 030^{b}	910^{ab}	1 370^{c}	630^{a}	***
Myosotis arvensis	1 540^{b}	2 690^{c}	650^{a}	880^{a}	***
Rumex acetosella	820^{a}	1 160^{b}	770^{a}	1 110^{b}	*
Polygonum aviculare	960^{b}	750^{ab}	560^{a}	980^{b}	**
P. lapathifolium	740	610	550	550	
P. convolvulus	690^{b}	540^{ab}	390^{a}	690^{b}	*
Alchemilla vulgaris	380^{ab}	630^{b}	430^{ab}	260^{a}	*
Lapsana communis	410^{b}	260^{b}	90^{a}	360^{b}	***
Whole material	44 190^{b}	65 060^{d}	35 220^{a}	57 270^{c}	

[1]) Values on the same line followed by the same letter do not differ significantly from each other.

arvensis (9 490), *Brassica* spp. (6 160), *Stellaria media* (4 300), *Viola arvensis* (2 520), *Ranunculus* spp. (2 210), *Galeopsis* spp. (1 280), *Carex* spp. (1 110) and *Myosotis arvensis* (1 050). Seeds of twelve further species or genera occurred in numbers exceeding 100 seeds/m². The list of the 21 most abundant species or genera includes the 20 species found to be most common, and the order of abundance in general follows that of frequency.

The soil samples analysed contained an average of 43 850 seeds/m²; regional variation was 30 890—56 790 and variation due to soil type 37 890—53 160. Considerable regional variation in abundance was found for many species. In most cases this variation was random, but for some species statistically significant differences were found, and these mostly corresponded to those already found in frequency. The same also applies to the differences due to soil type, especially considering the fact that the samples from fine mineral soils contained the largest numbers of seeds.

The relative distribution of the most common species by sampling districts was as follows:

District/ Species	*Chenopodium album*	*Spergula arvensis*	*Brassica* spp.	*Stellaria media*	*Viola arvensis*	*Ranunculus* spp.	*Galeopsis* spp.	*Carex* spp.	*Myosotis arvensis*	*Rumex acetosella*	Total
1	26	37	3	9	7	1	1	2	1	2	89
2	18	33	19	3	7	3	5	2	2	1	93
3	26	13	16	14	13	4	2	1	2	+	91
4	22	19	14	6	5	7	4	4	3	3	87
5	20	18	15	13	6	5	3	2	5	2	89
6	23	21	9	13	3	7	2	2	3	4	87
7	16	19	31	11	1	5	2	4	1	2	92
8	28	13	17	10	4	7	3	3	3	2	90
Total	23	22	14	10	6	5	3	3	2	2	90

Influence of preceding crop on the number of weed seeds

The distribution of the samples of the most abundant weed species between the commonest preceding crops was as follows: spring cereals 373, winter cereals 69, ley 244, potatoes and root crops 94 samples (cf. MUKULA et al. 1969). The preceding crop was not found to affect the frequencies of individual weed species but it did affect the numbers of their seeds present in the soil. Part of this variation was random, but for some species statistically significant differences were found. Table 3 shows the influence of the preceding crop upon the numbers of seeds of the 15 weed species most frequently encountered in this study (cf. Table 2). According to these data, ley had a strong reducing effect on the numbers of seeds of certain annuals and winter-annuals like *Chenopodium album*, *Stellaria media*, *Galeopsis* spp., *Myosotis arvensis* and *Lapsana communis*. Potatoes and root crops, on the other hand, increased the numbers of seeds of *Chenopodium album* and *Stellaria media* considerably. The highest total numbers of weed seeds in soil were found after cereals and potatoes and root crops (44 190—65 060 seeds/m^2), the lowest numbers after ley (35 220).

Discussion

The present study revealed an average of 43 850 weed seeds/m^2 in a 20-cm cultivated layer of Finnish arable land. The variation due to sampling district and soil type was 30 890—56 790. Dorph-Petersen (1910), who analysed four samples from a 16-cm layer, found an average of 135 500 seeds/m^2, of which 38 600 or 28 % (varying 14—55) were capable of germinating. Kropac (1966) investigated soils from two separate localities and found 19 900 and 70 300 seeds/m^2, respectively, of which he estimated 20 % (4 000 and 14 100 seeds) to be capable of germinating. Jensen (1968) studied 57 soil samples 20 cm thick and found an average of 87 000 seeds/m^2 (after elimination of *Juncus bufonius*), of which 23 000 or 26 % were viable. Many other research workers (Rasmussen 1928, Brenchley and Warington 1930, Roberts and Dawkins 1967) report 14 500—39 100 germinating weed seeds per m^2.

Great areal and local variation has been found to occur (cf. Kropac, op.cit.), even between different fields. Jensen (1968), for example, found a variation within the range of 12 600—933 800 seeds/m^2 (600—496 200 germinating seeds/m^2). In the present study the variation was between 3 000 and 390 000 seeds/m^2. The way in which the results are expressed (in terms of all seeds, viable seeds or germinating seeds) also affects the outcome. The germination percentage for weed seeds is, in general about 25. According to this, the total variation in the results obtained by various research workers is in the range of 20 000—160 000 seeds/m^2; The average abundance of seeds found in the present study (about 44 000) is roughly a quarter of this figure.

The numbers of seeds found and their distribution between the different species can, to some extent, be co-ordinated with the results of Mukula et al. (1969). The samples for the present study were collected from the same fields that were subjected to the 1962—64 weed survey. According to Mukula et al., there was wide variation in the numbers of weeds between the sampling districts (272—998/m^2) and the years (439—641/m^2). This was due to varying den-

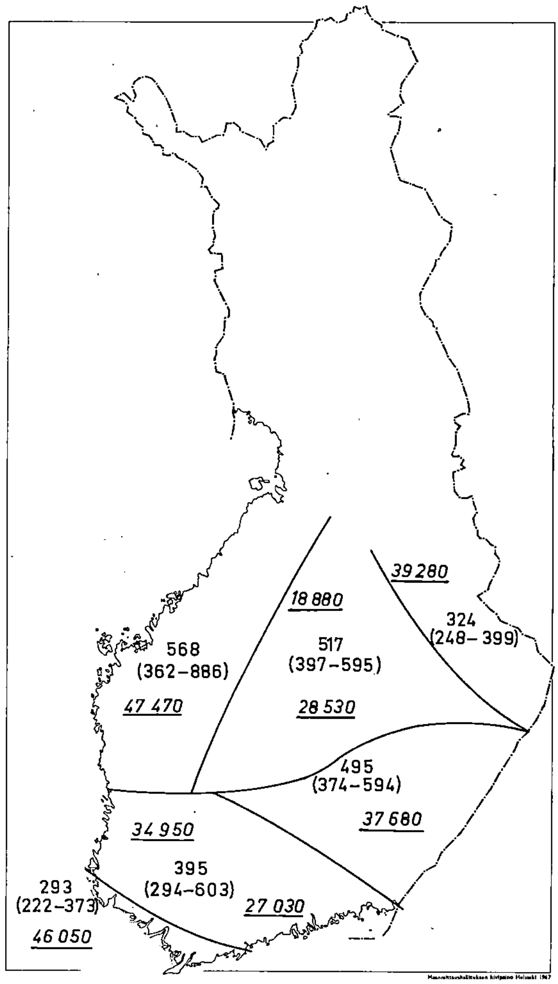

Fig. 2. Average numbers of plants of the abundant weed species (variation in brackets) and the numbers of seeds found in soil samples (underlined).

sities of the spring cereal stands as well as to differences in the germination of weed seeds in the varying weather conditions of the respective years. To even out the great variation, the present comparison is based on the three-year averages of 1962—64 calculated from the date of Mukula et al. in terms of the commonest species only (Table 2) and for the present material by omitting from Table 2 those species (e.g. *Brassica* and *Carex* spp.) that were classed as very rare by Mukula et al. (Fig. 2).

Figure 2 shows that the numbers of plants of the most abundant weed species varied greatly in all the sampling districts in 1962—64. The largest numbers, however, were recorded in Pohjanmaa (along the coast of the Gulf of Bothnia), in southeastern Finland and in areas in between (average 495—568/m^2), while the smallest numbers were found in the southwestern, southern and northeastern parts of the country (293—395/m^2). The over-all average was 455 plants/m^2. The number of weed seeds was 34 980/m^2 (18 880—47 470/m^2), on the average 77-fold (46—157); this indicates that of the seeds present in the soil, 0.6—1.3 % emerged in the south, southeast and northeast, 1.2—1.8 % in the other parts of the country, with an overall average of 1.3 %. Supposing that weeds emerge from the top centimetre of the soil, representing 1/20 of the total seed population present in the entire cultivated layer, one arrives at a theoretical germination figure of 25 %, with a regional variation of 12—44 (Dorph—Petersen 1910, Kropac 1966, Jensen 1968). The variation is apparently closely connected with the occurrence of *Chenopodium album* (cf. Table 2). The number of seeds of this species was many times greater than the number of plants recorded on the sampling plots, thus indicating a remarkably low theoretical germination, 12 %.

For many species the frequencies obtained in this study run fairly parallel to the values presented by Mukula et al., but in general lower values were found, particularly for the more uncommon species. This is probably mainly due to fact that the soil cores covered less than 1 % of the total 1 m^2 area on which the growing weeds were counted. For example, the frequencies estimated from seeds and from weeds were almost identical for *Chenopodium album* (92 and 91 %) and *Spergula arvensis* (88 and 81 %), but for some species *(Lapsana communis, Vicia* spp., *Matricaria inodora, Erysimum cheiranthoides, Raphanus raphanistrum)* the seed samples gave much lower frequencies than those calculated from the actual weed counts, so the two investigations apparently do not confirm each other in all respects. This also holds true of *Fumaria*, seeds of which were only rarely found in the present study, although the frequency of this species was 42 % and the abundance 5/m^2 in the survey by Mukula et al., as well as of the perennial species *Achillea millefolium* and *Agropyron repens*. On the other hand, Mukula et al. obtained a frequency value as low as 9 % for *Brassica* spp., while the present study gave a frequency of 89 %, with 6 160 seeds/m^2. One reason for this discrepancy is probably that seeds of *Brassica campestris*, formerly a very common weed in Finland (Grotenfelt 1924, Hiitonen 1933, Lagerberg et al. 1939), still persist in Finnish soils, although with a greatly reduced germinating capacity. Mukula et al. (op. cit.) found *Brassica* in large numbers in certain districts (over 10 % frequency in 6 districts, maximum 28 %) but in several others it was not recorded at all.

Most of the abundance values presented here are considerably higher than those obtained by Mukula et al. This result was fully predictable, however, as only a fraction of the seeds present in the soil actually do germinate and even this only applies to those in the top centimetre of the soil. The germinating capacity of certain of the main weed species will therefore be studied in supplementary investigations.

Summary

The Department of Plant Husbandry of the University of Helsinki conducted a study of the weed seed populations in the soils of southern and central Finnish arable fields.

The sample material was collected by the Department of Plant Husbandry, Agricultural Research Centre, Tikkurila, in 1964 and consisted of 815 soil samples from eight different districts, which gives an average of 102 samples per district. The frequencies and abundances of the commonest weed species and genera were calculated by sampling districts, by different types of soil, and by preceding crops. The following results were obtained:

1. The most frequent weed seeds were those of *Chenopodium album* (91 %), *Brassica* spp. (89), *Spergula arvensis* (81), *Ranunculus* spp. (79), *Galeopsis* spp. (70), *Viola arvensis* (63), and *Stellaria media* (62). For 21 species the frequency was at least 10 %, for 34 species at least 3 % of the samples (Table 1).

2. Areal differences in frequency were found for seeds of many species. *Brassica*, *Ranunculus* and *Galeopsis* spp. were less frequent in district 1 than elsewhere. *Alchemilla vulgaris* was most frequent in samples from the east of Finland, least frequent in district 6 in the west of Finland. *Galium* spp., *Rumex domesticus* and *Thlaspi arvense* were remarkably common in district 3. In the northernmost districts 6—8, *Lapsana communis* and *Scleranthus annuus* were less frequent than elsewhere.

3. Soil type had a significant influence upon the occurrence of seeds of 15 species (Table 1). In coarse mineral soils, *Galeopsis* spp. were more common, and *Lamium* spp. less common than in other types of soil. In clay soils, *Stellaria media* and *Lapsana communis* were more frequent, *Polygonum lapathifolium*, *Rumex acetosella*, *Anthoxanthum odoratum* and *Potentilla* spp. less frequent than in other soils. In peat soils, *Carex* spp. were more frequent, and *Viola arvensis*, *Polygonum aviculare*, *P. convolvulus*, *Myosotis arvensis*, *Taraxacum vulgare* and *Scleranthus annuus* less frequent than in other soils.

4. The most abundant species were *Chenopodium album* (10 020 seeds/m^2), *Spergula arvensis* (9 490), *Brassica* spp. (6 160), *Stellaria media* (4 300), *Viola arvensis* (2 520), *Ranunculus* spp. (2 210), *Galeopsis* spp. (1 280), *Carex* spp. (1 110) and *Myosotis arvensis* (1 050) (Table 2). Seeds of twelve other species were found in numbers exceeding 100/m^2. The average number of weed seeds in the samples was 43 850/m^2.

5. The numbers of seeds of some species varied according to sampling district and soil type. These variations mainly coincided with the variations in frequency (Table 2).

6. The ten most abundant species made up 90 % of the total number of seeds (cf. p. 4). The highest proportions were those of *Chenopodium album* (23), *Spergula arvensis* (22), *Brassica* spp. (14) and *Stellaria media* (10).

7. The preceding crop affected the numbers of seeds of certain species (Table 3). Seeds of *Chenopodium album*, *Stellaria media*, *Galeopsis* spp., *Myosotis arvensis* and *Lapsana communis* were less numerous after leys than after any other crops. Potatoes and root crops allowed an increase in the seed populations of *Chenopodium album* and *Stellaria media* in the soil. The total number of weed seeds was largest after potatoes and root crops (65 060/m^2) and cereals (44 190/m^2), smallest after ley (35 220/m^2).

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SELOSTUS

Suomen peltomaiden rikkasiemenistö

JUHANI PAATELA ja LEILA-RIITTA ERVIÖ

Helsingin yliopiston Kasvinviljelytieteen laitos

Helsingin yliopiston Kasvinviljelytieteen laitoksella Viikissä suoritettiin vuosina 1964—1967 tutkimus Etelä- ja Keski-Suomen peltomaiden ruokamultakerrokseen varastoituneesta rikkasiemenistöstä. Aineisto oli kerätty kahdeksalta eri alueelta (kuva 1) ja käsitti kaikkiaan 815 maanäytettä. Tutkimuksessa määritettiin tärkeimpien rikkasiemenlajien tai -sukujen yleisyys ja runsaus kullakin tutkimusalueella, eri maalajeilla sekä erilaisten esikasvien jälkeen. Tulokset olivat seuraavat:

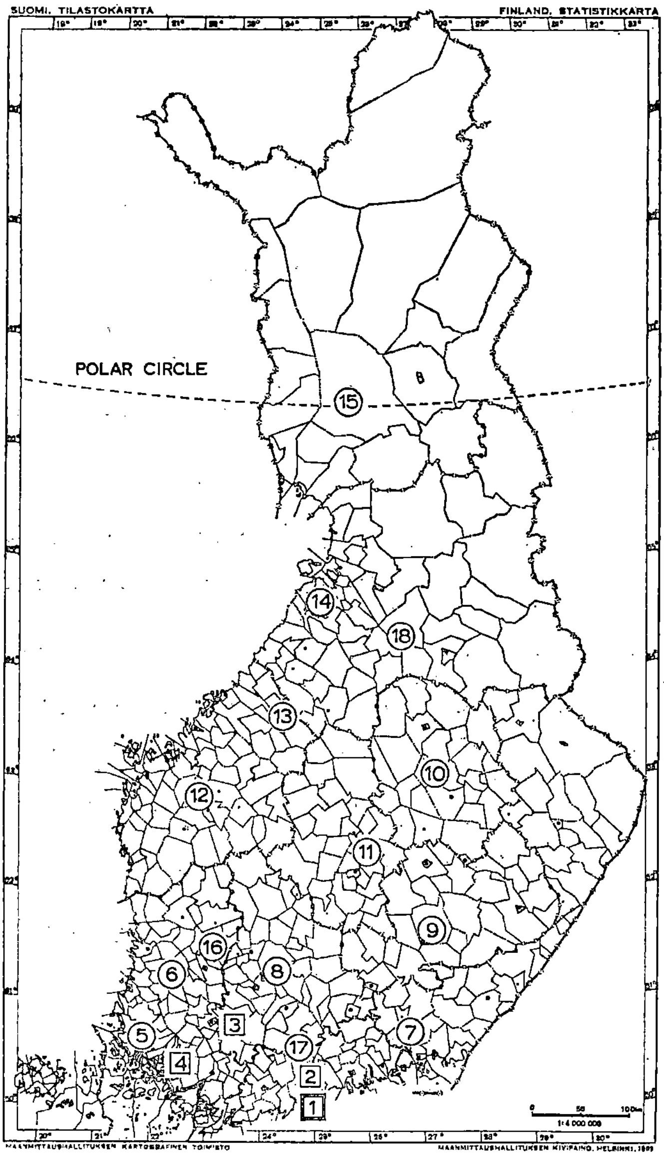
1. Yleisimmät rikkasiemenlajit olivat *Chenopodium album* (91 %), *Brassica* spp. (89), *Spergula arvensis* (81), *Ranunculus* spp. (79), *Galeopsis* spp. (70), *Viola arvensis* (63) ja *Stellaria media* (62) (taulukko 1).

2. *Brassica*-, *Ranunculus*- ja *Galeopsis*-sukujen siemeniä tavattiin harvemmin alueella Korppoo—Nauvo kuin muualla. Lajin *Alchemilla vulgaris* siemeniä tavattiin useimmin maan itäosissa. Lajit *Galium* spp., *Rumex domesticus* ja *Thlaspi arvense* olivat yleisimpiä alueella 3. Alueilla 6—8 olivat lajien *Lapsana communis* ja *Scleranthus annuus* siemenet harvinaisempia kuin muualla.

3. *Galeopsis* spp. oli yleisin karkeilla kivennäismailla, *Stellaria media* ja *Lapsana communis* savimailla sekä *Carex* spp. turvemailla (taul. 1). *Polygonum lapathifolium*, *Rumex acetosella*, *Anthoxanthum odoratum* ja *Potentilla* spp. olivat harvinaisia savimailla. *Lamium* spp. oli karkeilla kivennäismailla harvinaisempi kuin muilla maalajeilla.

4. Peltomaissa runsaimmin esiintyneet lajit olivat *Chenopodium album* (10 020 kpl/m^2), *Spergula arvensis* (9 490), *Brassica* spp. (6 160), *Stellaria media* (4 300), *Viola arvensis* (2 520), *Ranunculus* spp. (2 210), *Galeopsis* spp. (1 280), *Carex* spp. (1 110) ja *Myosotis arvensis* (1 050) (taul. 2).

5. *Chenopodium album*-, *Stellaria media*-, *Galeopsis*-, *Myosotis arvensis*- ja *Lapsana communis*-lajien siemeniä oli maassa vähiten nurmen jälkeen (taul. 3). Peruna ja juurikasvit lisäsivät lajien *Chenopodium album* ja *Stellaria media* siemenvarastoa maassa. Kaikkiaan oli rikkasiemeniä maassa vähiten nurmen jälkeen.



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