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YLIJOHTAJA, PROFESSORI JOUKO VUORISEN JUHLAJULKAISU

JUBILEE ISSUE IN HONOUR OF PROFESSOR JOUKO VUORINEN DIRECTOR GENERAL OF THE AGRICULTURAL RESEARCH CENTRE

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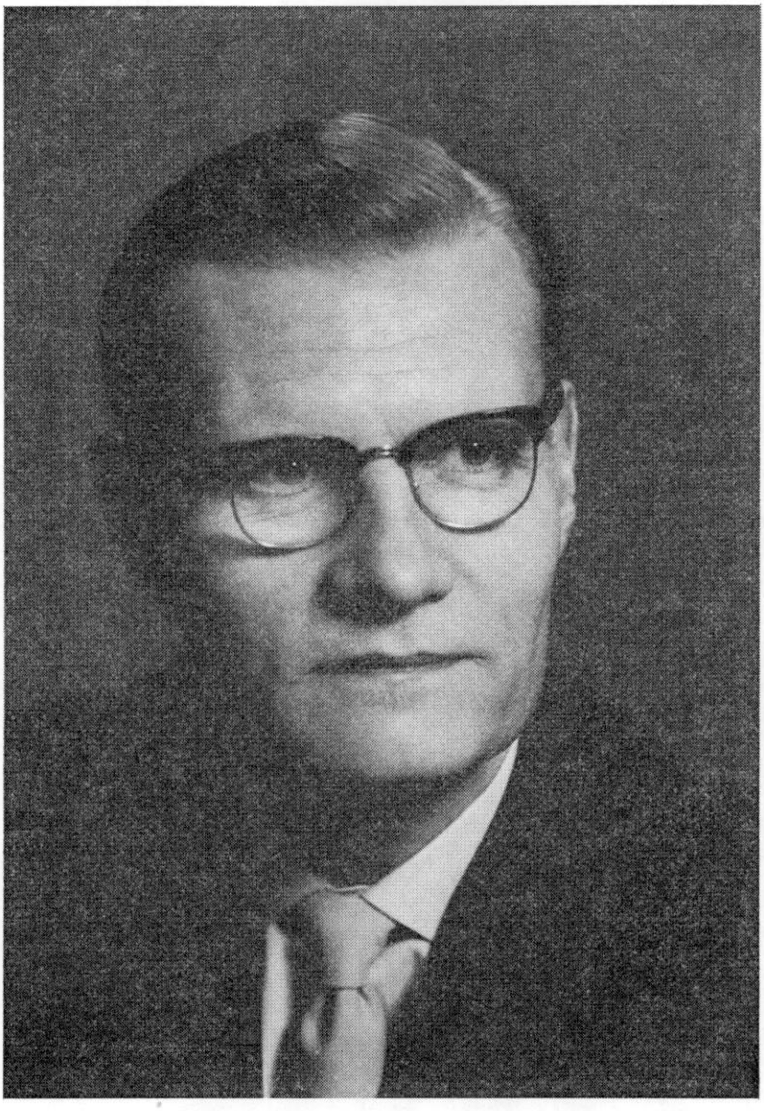
Maatalouden tutkimuskeskuksen ylijohtajan (1960—73), professori Jouko Ensio Vuorisen täyttäessä 70 vuotta lokakuun 16. päivänä 1980 ovat Maatalouden tutkimuskeskus, Annales Agriculturae Fenniae ja Jouko Vuorisen entiset työtoverit halunneet häntä kohtaan tuntemansa kunnioituksen ja kiitollisuuden osoituksena toimittaa tämän juhlajulkaisun.

Professor Jouko Ensio Vuorinen, Director General of the Agricultural Research Centre (1960—73) will be 70 years old on October 16, 1980. The Agricultural Research Centre, Annales Agriculturae Fenniae and his former collegues wish to have this jubilee issue edited in honour of this occasion as a token of their respect and gratitude.



Jouko Vuorinen

JOUKO VUORINEN

Jouko Ensio Vuorinen syntyi 16. lokakuuta 1910 Turussa, jossa hän myös aloitti opintonsa ja tuli ylioppilaaksi Turun Suomalaisesta lyseosta 1930. Maatalous- ja metsätieteiden kandidaatin tutkinnon sekä agronomin tutkinnon hän suoritti 1937 pääaineenaan maanviljelyskemia ja -fysiikka. Hänellä oli molemmissa tutkinnoissa korkein arvosana myös maanviljelysopissa, sekä agronomitutkinnossa lisäksi kansantaloudessa ja maanviljelystaloudessa. Jouko Vuorinen julkaisi tohtorinväitöskirjansa 1939, suoritti maatalous- ja metsätieteiden lisensiaatin tutkinnon 1940 ja sai samana vuonna maatalous- ja metsätieteiden tohtorin arvon.

Laajojen opintojensa lisäksi Jouko Vuorinen oli hankkinut myös käytännön kokemusta maatalouden alalla sekä kotitilallaan että toimimalla 2½ vuotta tilanhoitajana Somerniemellä. Nämä yhdessä loivat vankan pohjan hänen tulevalle elämänuralleen maataloustutkijana ja myöhemmin maataloustutkimuksen johtajana.

Jouko Vuorisen tutkijanura alkoi varsinaisesti 1937, jolloin hän tuli Maatalouden tutkimuskeskuksen (vuoteen 1957 Maatalouskoelaitos) maantutkimusosaston palvelukseen. Tällä osastolla hän suoritti mittavan työn hoitaen ensimmäisten viiden vuoden aikana osaston ylimääräisen kemistin tointa ja nuoremman agrogeologin virkaa sekä seuraavat viisi vuotta vanhemman agrogeologin virkaa. Jatkosodan aikana hänet komennettiin suorittamaan maaperätutkimuksia Aunuksessa sekä hoitamaan maatalousupseerin tehtäviä. Vuonna 1947 Jouko Vuorinen nimitettiin maantutkimusosaston johtajan ja professorin virkaan. Tätä virkaa hän hoiti aina vuoteen 1960 asti. Noin vuoden ajan, 1950—51, hän hoiti oman virkansa ohella myös maanviljelyskemian ja -fysiikan osaston avoinna olevaa johtajan virkaa. Vuonna 1960 Jouko Vuorisen kykyjä, tietoja ja kokemusta tarvittiin hoitamaan vielä laajempaa sektoria, koko maatalouden käsittävää tutkimuskenttää ja hänet nimitettiin Maatalouden tutkimuskeskuksen ylijohtajaksi. Ylijohtajan virkaa hän hoiti vuoteen 1973, eläkkeelle siirtymiseensä saakka.

Virka- ja tutkimustehtäviensä ohella Jouko Vuorinen toimi myös opettajana ollen maantutkimuksen dosenttina Helsingin yliopistossa vuosina 1947—61 ja häntä käytettiin asiantuntijana useita professorin ja dosentin virkoja täytettäessä. Hänen laajaa asiantuntemustaan on käytetty hyväksi valtion eri laitosten johtokunnissa sekä lukuisissa komiteoissa ja toimikunnissa. Hän toimi mm. valtion maantutkimus- ja kasvinviljelykomitean puheenjohtajana 1948—51, typpiomavaraistoimikunnan puheenjohtajana 1950—51, Valtion maatalouskemian laitoksen johtokunnan jäsenenä vuodesta 1950 ja puheenjohtajana 1961—74, hedelmä- ja marjatalouskomitean jäsenenä 1954—58, Seutusuunnitelmien Liiton Yhtenäistämistoimikunnan asiantuntijana 1960, Maatalouden tutkimuskeskuksen edustajana Maatalouskoneiden tutkimussäätiön hallintoneuvostossa 1963—73, valtion maatalous-metsätieteellisen toimikunnan jäsenenä 1961—70, Maatalouskeskusten Liiton johtokunnan asiantuntijajäsenenä 1961—75, rehu- ja lannoitesäännöstoimikunnan puheenjohtajana

1961—65, maataloudellisen elintarviketutkimuksen järjestelytoimikunnan puheenjohtajana 1962—64, Maatalouden taloudellisen tutkimuslaitoksen neuvottelukunnan puheenjohtajana 1962—73, maaseudun rakennusasiain neuvottelukunnan jäsenenä 1962—70, maatalousministeriön edustajana Raision Tehtaiden Tutkimussäätiön hallituksessa 1963—74, Suomessa 1966 pidetyn X kansainvälisen nurmikongressin päätoimikunnan puheenjohtajana, valtion tiedeneuvoston jäsenenä 1967—72, Työtehoseuran rakennustoimikunnan jäsenenä 1968—70, Maatilatalouden kehittämisrahaston tutkimusasiain neuvottelukunnan jäsenenä 1969—72, maatalouden tutkimus- ja tarkastuskomitean jäsenenä 1969—72, kehitysalueiden neuvottelukunnan pysyvänä asiantuntijana 1970—73, maatalousministeriön lyijysaastekomitean puheenjohtajana 1970 ja vesihallinnon tieteellisen neuvottelukunnan jäsenenä 1971—74.

Jouko Vuorinen on osallistunut aktiivisesti myös ammatilliseen ja tieteelliseen yhdistystoimintaan kuuluen mm. Agronomien yhdistyksen johtokuntaan 1944—46, Hedelmänviljelijäin yhdistykseen, puheenjohtajana 1954—70 ja kunniapuheenjohtajana v:sta 1970, Puutarhaliiton johtokuntaan 1956—63, Suomen Maataloustieteelliseen Seuraan, puheenjohtajana 1950, Pohjoismaiden Maataloustutkijain Yhdistykseen, Suomalaisten kemistien seuraan, Suoseuraan, Kansainväliseen maaperätieteelliseen Seuraan (ISSS) ja on Norjan suoseuran (Det Norske Myrselskap) kirjeenvaihtajajäsen ja Neuvostoliiton maataloustieteellisen Akatemian ulkomainen jäsen.

Kirkollisen elämän ja seurakuntatyön piirissä Jouko Vuorinen on hoitanut merkittäviä luottamustehtäviä. Hän on ollut mm. Evankelisen Ylioppilasliiton hallituksen puheenjohtaja 1950 ja kunniajäsen v:sta 1962, Suomen Luterilaisen Evankeliumiyhdistyksen johtokunnan jäsen v:sta 1942 ja puheenjohtaja v:sta 1947, Luterilaisen maailmanliiton suomalaisen kansalliskomitean jäsen 1947—70 sekä Suomen kirkon edustajana Luterilaisen maailmanliiton kongressissa Hannoverissa 1952 ja sen kirkkojen välisen yhteistyön ja Japanissa toimivien luterilaisten lähetysten kokouksessa Tokiossa 1971.

Maanpuolustustehtäviin on Jouko Vuorinen osallistunut paitsi sotien aikana rintamajoukoissa myös sotien jälkeen. Hän osallistui maanpuolustuskursseihin Sotakorkeakoulussa 1965 ja 1971. Hän oli Säteilyvalvonnan järjestelytoimikunnan jäsen 1962—65, puolustustaloudellisen suunnittelukunnan tutkimusjaoston jäsen 1966—70 ja osallistunut maanpuolustuksen tieteellisen neuvottelukunnan (MATINEn) eri jaostojen ja työryhmien työhön 1968—73. Jouko Vuoriselle on myönnetty mm. VR 4 m.k., SL K ja SVR K. Hän on sotilasarvoltaan majuri.

Kansainvälisen tieteellisen yhteistyön välttämättömyys Suomen kaltaiselle pienelle maalle, jonka omat tutkimusresurssit ovat vähäiset, on ollut itsestään selvä Jouko Vuoriselle jo hänen tutkijanuransa alkuajoista lähtien ja erityisesti hänen ollessaan vastuussa Suomen maataloustutkimuksesta Maatalouden tutkimuskeskuksen ylijohtajana. Pitkän uransa aikana hän loi hyvät suhteet lukuisiin ulkomaisiin tutkijoihin ja tutkimuslaitoksiin sekä pohjoismaisella tasolla että myös muualla Euroopassa ja sen ulkopuolella. Hän suoritti monia opinto- ja tutkimusmatkoja pohjois- ja muihin Euroopan maihin sekä Euroopan ulkopuolelle mm. Marokkoon, Lounais-Afrikkaan, Keniaan, Etiopiaan, USA:han, Kanadaan ja Japaniin. Näillä matkoilla hän tutustui sekä eri maiden maatalouden yleispiirteisiin että erikoisuuksiin mutta ennen kaikkea niiden maataloustutkimuksen saavuttamiin tuloksiin ja maataloustutkimuksen organisaatioon. Hän on tarkka havainnoitsija, mistä osoituksena ovat hänen suuren valokuvamateriaalin täydentämät kriittiset matkakuvauksensa ja julkaisemansa matkakertomukset (kts. julk.luettelo, esim. n:ot 44, 45, 57, 73, 78, 79, 88, 95, 102 ja 103).

Kansainvälisten tieteellisten järjestöjen, ennen kaikkea Pohjoismaiden maataloustutkijain yhdistyksen (PMY) ja Kansainvälisen maaperätieteellisen seuran (ISSS), työhön on Jouko Vuorinen antanut huomattavan työpanoksen. Hän toimi aktiivisesti näiden järjestöjen eri komiteoissa ja työryhmissä parin vuosikymmenen aikana ja osallistui PMY:n kongresseihin vuosina 1947, 1953, 1956 ja 1963 sekä ISSS:n kongresseihin vuosina 1952 (Dublin), 1960 (Madison, USA), 1964 (Bucarest) ja maan kastelua koskevaan välikongressiin Kööpenhaminassa 1958.

Erityisen merkittävä on Jouko Vuorisen osuus ollut YK:n elintarvike- ja maatalousjärjestön FAO:n toiminnassa. Hän toimi Suomen FAO-neuvottelukunnan jäsenenä kolme kolmivuotiskautta 1961—69 ja osallistui mm. FAO:n 16. yleiskokoukseen Suomen valtuuskunnan jäsenenä 1971.

FAO/Euroopan maatalouskomission (ECA) eksekutiivikomitean jäsenenä hän oli 1970—72 osallistuen sen 45.—52. istuntoihin Roomassa, Pariisissa ja Bonnissa. FAO/ECA:n maa- ja vesivarojen käyttöä tutkivan alakomitean työhön ja kokouksiin Jouko Vuorinen osallistui vuosina 1956—63. Ehkä voimakkaimman panoksensa FAO/ECA:n työkentässä Jouko Vuorinen antoi sen maaperäkartoituskomitealle, jonka jäsenenä hän oli vuosina 1957—71 ja puheenjohtajana 1969—71. Tämän komitean, joka toimi yhteistyössä ISSS:n kanssa, työn tuloksena syntyi ensimmäinen Euroopan maaperäkartta (1 : 2,5 milj.). Mainittakoon, että Jouko Vuorinen oli päävastuussa Suomen osuudesta siihen, ja suureksi osaksi hänen ansiotaan on myös se, että tämän työn suorittamisessa saumattomalla pohjoismaisella yhteistyöllä oli merkittävä osuus.

Myös muussa kansainvälisessä yhteistyössä Jouko Vuorinen oli mukana osallistumalla mm. OECD:n maatalouskomitean ja Pohjoismaisen maataloustutkimuksen yhteistyöelimen (NKJ) työhön ja maatalouden alalla toimivien kansainvälisten järjestöjen 17. konferenssiin Pariisissa 1973.

Jouko Vuorisen tieteellinen tutkimustoiminta ajoittui lähinnä hänen tutkija- ja johtajakaudelleen maantutkimuslaitoksessa ja kohdistui ensisijaisesti maaperän kemiallisiin ja fysikaalisiin ominaisuuksiin ja maan viljavuuteen vaikuttavien tekijöiden selvittämiseen sekä agrogeologiaan. Hänen tieteellistä tutkimustyötään ja sen kohteiden valintaa ohjasi voimakas pyrkimys tutkimustulosten soveltamiseen käytännön maatalouteen. Hän on myös esimerkillisen hyvin ja selkeästi tiedottanut tutkimustensa tulokset viljelijöille ja neuvontahenkilöstölle ns. kansantajuisina julkaisuina. Luettelo Jouko Vuorisen tärkeimmistä julkaisuista on tämän niteen sivuilla 61—64.

Jouko Vuorisen väitöskirja »Untersuchungen über die Koagulation des schweren Glazialtons» käsittelee jäykän glasiaalisaven koagulaatiota ja on hänen ensimmäinen tieteellinen julkaisunsa. Hän ei kuitenkaan rajoittanut tutkimuksiaan monen tutkijan tavoin suppeaan aihepiiriin, vaan ryhtyi jo tutkijauransa varhaisessa vaiheessa selvittämään muita maaperäkemian ja -fysiikan piiriin kuuluvia kysymyksiä. Näistä ensimmäisten joukossa olivat hänen maan humusta ja typpitaloutta koskevat tutkimuksensa (julk. luettelossa esim. n:ot 8, 27, 31) ja vähän myöhemmin monet maaperän vesi- ja lämpöoloja sekä rakennetta koskevat tutkimukset (esim. n:ot 71, 77, 82, 90, 93, 94, 97).

Jouko Vuorisen johdolla on laadittu huomattava määrä agrogeologisia karttoja, jotka ovat lisänneet tietoutta maamme maaperän laadusta, eri maalajien levinneisyydestä ja käyttöarvosta hyödyntäen sekä maataloutta että maaperän käytön suunnittelua. Tästä aiheesta hän on itsekin julkaissut useita kirjoituksia (mm. n:ot 7, 10, 19, 65, 87, 99, 104, 105).

Jouko Vuorinen oivalsi jo varhain, että maan ravinteisuuden tunteminen kuuluu järkevän viljelyn perusvaatimuksiin ja siksi hän paneutuikin erityisellä tarmolla tämän tutkimusalan, viljavuustutkimuksen, kehittämiseen ja soveltamiseen käytäntöön. Merkittävä osa hänen julkaisutoiminnastaan (mm. n:ot 11, 15, 16, 23, 29, 32, 33, 34, 35, 36, 37, 38, 40, 41, 42, 47, 49, 51, 54, 55, 56, 58, 59, 61, 63, 67, 72, 75, 88, 107, 112) käsitteleekin viljavuustutkimusta, siinä käytettäviä menetelmiä, tulosten tulkintaa ja soveltamista käytännön viljelyyn sekä pelloilla ja hedelmätarhoissa että kasvihuoneissa. Jouko Vuorinen on pysyvästi kirjoittanut nimensä

Suomen viljavuustutkimuksen historiaan. Häntä voidaan pitää maamme nykyisen viljavuustutkimuksen perustajana, ja siitä järjestelmästä, joka hänen johdollaan 1940-luvun lopulla luotiin, on runko edelleen käytössä.

Jouko Vuorinen kuuluu myös järjestelmällisen hivenainetutkimuksen uranuurtajiin Suomessa, jossa verrattain laajamittaiset hivenaineiden esiintymistä maaperässä selvittävät tutkimukset pääsivät alkuun paljon aikaisemmin kuin useissa muissa maissa. Nämä tutkimukset teki mahdolliseksi Jouko Vuorisen maantutkimuslaitokselle 1952 hankkima spektrografi. Se oli erittäin harvinainen tutkimusväline tuohon aikaan, ensimmäinen Suomessa ja pitkään maamme ainoa. Tältä tutkimussektorilta hänen tärkein julkaisunsa on »On the amounts of minor elements in Finnish soils» (n:o 81), jossa suureen näyteaineistoon perustuen selvitetään kymmenen hivenaineen totaalimääriä ja niiden esiintymistä Suomen eri maalajeissa.

Maatalouden tutkimuskeskuksen ylijohtajana Jouko Vuorinen toimi 13 vuoden ajan. Hänen harkitsevana ja tasapuolisena hallintomiehenä saamansa luottamus auttoi epäilemättä hänen pyrkimyksiään kehittää maataloustutkimusta ja tutkimuskeskusta. Hänen ylijohtajakautenaan tutkimuskeskukseen perustettiin mm. kaksi uutta yksikköä, laskentatoimisto ja isotooppilaboratorio, Jokioisten kartanot siirrettiin tutkimuskeskuksen hallintaan, rakennettiin uudet laitosrakennukset kolmelle laitokselle Tikkurilassa, kasvinjalostuslaitokselle Jokioisissa, sikatalouskoeasemalle Hyvinkäällä ja kohennettiin muidenkin yksiköiden toimintaedellytyksiä sekä toimitilojen että henkilöstön suhteen. Huolimatta tuon ajan maataloutta ja tutkimusta vieroksuvista asenteista ja valtion kireästä määrärahapolitiikasta Maatalouden tutkimuskeskuksen henkilökunta kaksinkertaistui näiden 13 vuoden aikana.

Ylijohtajana Jouko Vuorinen oli kunnioitettu ja pidetty. Hän pyrki luomaan tutkimuskeskukseen innostavan yhteishengen ja hyvät henkilökohtaiset suhteet alaisiinsa johtajiin ja tutkijoihin ja onnistui näissä pyrkimyksissään kiitettävällä tavalla. Hän seurasi tarkasti jokaisen laitoksen ja koeaseman toimintaa ja paneutui niiden ajankohtaisiin kysymyksiin mm. vierailemalla kullakin näistä vähintäin kerran vuodessa. Hän ymmärsi myös tutkimuksen ja neuvonnan yhteistyön merkityksen ja huolehti siitä mm. koetoimintapäivien muodossa ja järjestämällä lukuisia muita vapaamuotoisia keskustelu- ja neuvottelutilaisuuksia. Hänen aloitteestaan tutkimuskeskus sai myös oman tieteellisen julkaisusarjansa »Annales Agriculturae Fenniae», jonka ensimmäinen numero ilmestyi v. 1962.

Saavutettuaan eläkeiän Jouko Vuorinen pääsi henkilökohtaisesti soveltamaan laajoja tietojaan käytännön maatalouteen. Muutamassa vuodessa hän on luonut Lohjan Kirkniemestä ostamastaan rappiotilasta mallitilan, jolla hän nyt harjoittaa maa- ja metsätaloutta sekä erityisesti hedelmä-, puutarhan- ja mehiläisten hoitoa, joihin hän aina on tuntenut suurta kiinnostusta.

Koko Jouko Vuorisen ansiokkaan tutkija- ja johtajauran ajan on hänen tukenaan ollut hänen puolisonsa Kerttu, joka itsekin agronomina on asiantuntevasti ja kiinteästi seurannut miehensä työtä, osallistunutkin siihen ja on epäilemättä ollut suurena henkisenä tukena monina ratkaisun hetkinä.

Professori Jouko Vuorisen ylijohtajakauden aikaiset tutkijakolleegat Maatalouden tutkimuskeskuksessa esittävät Jouko Vuoriselle kunnioittavat kiitoksensa hänen suorittamastaan suuriarvoisesta työstä Suomen maatalouden hyväksi.

Toukokuun 15. päivänä 1980

Mikko Sillanpää

Paavo Elonen	Martti Markkula
Martti Lampila	Jaakko Mukula
Ulf Lindström	Jaakko Säkö
Rolf Manner	Aarre Ylimäki

JOUKO VUORINEN

Professor Jouko Ensio Vuorinen was born on 16th October 1910 in Turku, where he also graduated from senior secondary school. He was awarded the degree of Agronomist and Master of Agriculture and Forestry in 1937, and Licenciate and Doctor of Agriculture and Forestry in 1940.

In addition to theoretical studies, Jouko Vuorinen gained experience in practical agriculture on his home farm and in his role as manager of a farm estate for two and a half years.

He started his scientific career in 1937 as a Chemist at the Institute of Soil Science, Agricultural Research Centre. Here he held the posts of Junior and Senior Agrogeologist and was nominated as the Director and Professor of the Institute in 1947. In 1960 he was nominated to the position of Director General of the Agricultural Research Centre, which he occupied until his retirement in 1973.

Beside his main occupation as a scientist, Jouko Vuorinen was lecturing in soil science at the University of Helsinki in 1947—61. His vast knowledge and ability was highly appreciated by governmental authorities, by the private sector as well as by scientific and professional organizations and he was invited to numerous committees and boards of directors, where he acted as chairman or as a member. He also played an active role in the congregational work of the Finnish Evangelical Lutheran Church.

Jouko Vuorinen realized the necessity for international scientific cooperation for a small country like Finland at an early stage in his scientific career and especially when responsible for agricultural research as the Director General of the Agricultural Research Centre. During his long career he built up good relations with numerous foreign scientists and scientific institutes in Europe as well as in other continents. He travelled widely in different parts of the world, was an excellent observer and wrote precise travel reports, many of which were published.

Jouko Vuorinen took an active part in the work of several international scientific organizations such as NJF (Scandinavian Association of Agricultural Scientists) and ISSS (International Society of Soil Science). His activities in the area of the Food and Agriculture Organization of the United Nations (FAO) deserve special mention. He was a member of Finland's FAO Committee for nine years and participated in the 16th FAO Conference in 1971 as a member of the Finnish delegation. He served as a member of the Executive Committee of the FAO/European Commission on Agriculture (ECA) for the period 1970—72, and took part in the work of several FAO/ECA subcommittees and working groups.

Jouko Vuorinen's research work was mainly carried out during his time at the Institute of Soil Science as a scientist and as the Director. His principal line of research consisted of the chemical and physical properties of soil and agrogeology. He was particularly interested in the study of factors affecting soil fertility and his name will remain permanently in the history of soil testing in Finland. He was also one of Finland's pioneers in the field of microelement research. A list of his main publications is given on pages 61—64 of this issue.

Jouko Vuorinen's fair and impartial judgements and skill as an administrator helped him in developing the Agricultural Research Centre. During the period 1960—73 when he was the Director General, many of the institutes and experimental stations received new laboratory and other buildings and the general conditions for demanding agricultural research work and experimentation were greatly improved. For example, this period saw the doubling of the personnel of the Research Centre. He was well liked and highly respected at the Research Centre, and was able to create an inspiring and enthusiastic spirit among his personnel.

JOUKO VUORISEN JULKAISUJA
PUBLICATIONS BY JOUKO VUORINEN

1939

1. Untersuchungen über die Koagulation des schweren Glazialtons. (Selostus: Jäykän glasiaalisaven koagulaatiota koskevia tutkimuksia.) Agrogeol. Julk. 50: 1—114. (Väitöskirja)

1941

2. Maanparannusaineiden käytöstä. Maatalous 34: 10—13.
3. Lannoitus. Joka talon opas 1: 1—161. Helsinki. (Aarnio, B. & Vuorinen, J. E.)

1944

4. Karbonaattisaostumista eräissä etelä-Suomen glasiaalisavissa. (Referat: Karbonatausfällung in einigen südfinnischen Glazialtonen.) Maatal.tiet. Aikak. 16: 16—35. Agrogeol. Julk. 54: 1—20.
5. Aunuksen Karjalan maaperästä. Maatalous 37: 40—46.

1945

6. Maamme maaperätutkimuksesta. Pellervo 46: 542—543.

1946

7. Agrogeologisesta maaperäkartoituksesta. Koetoim. ja Käyt. 3: 6—8.
8. Maaperän humuksen määrittämisestä. Maatal.tiet. Aikak. 18: 11—24.
9. Koekenttien maaperän epätasaisuudesta. (Summary: Inequality of soil in test fields). Maatal.tiet.Aikak. 18: 125—135.
10. Nummi—Pusula. (Summary: Soil map 13, Nummi—Pusula.) Agrogeol. Kartt. 13: 1—50.
11. Viljelyksen vaikutuksesta maaperän viljavuuteen. (Summary: The influence of cultivation on the fertility of soil.) Agrogeol. Julk. 56: 1—60.

1948

12. Perusteellisen maatutkimuksen mahdollisuuksista Suomen viljelysmailla. Koetoim. ja Käyt. 5: 9—12.

1949

13. Maan viljavuustutkimus — lannoitussuunnitelma. Koetoim. ja Käyt. 6: 1.
14. Uudismaiden multavuudesta ja ravinteisuudesta. Koetoim. ja Käyt. 6: 2.
15. Viljavuustutkimus maatalouden palveluksessa. Maatalous 42: 264—267.
16. Maan viljavuuden tutkiminen. Rikkihappo- ja superfosfaattitehtaat: »Väkilannoitteiden hankinta- ja käyttötavoitteista Suomessa»: 63—65.
17. Maaperäsanaston ja maalajien luokituksen tarkistus v. 1949. (Summary: A critical review of soil terminology and classification in Finland in the year 1949.) Maatal.tiet. Aikak. 21: 37—66. (Myös ruotsiksi; yhdessä kymmenen muun tutkijan kanssa).
18. Maantutkimus- ja kasvinviljelyskomitean mietintö. (Komitea: puh.joht. Jouko Vuorinen. Jäs. Väinö Suuronen, Matti Annila ja siht. Olavi Linkola.) Komiteanmietintö n:o 4. 46 p.

1950

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ANNALES AGRICULTURAE FENNIAE, VOL. 19: 65—70 (1980)

Seria AGROGEOLOGIA ET -CHIMICA N. 97 — Sarja MAA JA LANNOITUS n:o 97

SOME REFLECTIONS ON THE PROBLEMS OF SOIL RATING

J. LÅG

LÅG, J. 1980. **Some reflections on the problems of soil rating.** Ann. Agric. Fenn. 19: 65—70. (Agr. Univ. of Norway, Ås—NHL.)

References are made to same older publications dealing with the classification of areas according to site quality.

The expression solbonmetri has been introduced to describe the line of research into soil rating on the basis of estimation of different soil factors.

In Norway, investigations of forest soils over large areas have been carried out at the same time as determination of the increment of the trees. Examples of relationships between site quality class and depth of soil material, main profile type, and thickness of humus layer, respectively, are mentioned.

Index words: Soil rating.

INTRODUCTION

Knowledge of the variation in production capacity of different soils has existed ever since man developed agriculture, and empirically founded information on such problems has been passed from generation to generation. However, wellgrounded knowledge of these relationships could not be developed until a certain scientific maturity was reached.

The discovery of chemical and biological laws late in the eighteenth and early in the nineteenth centuries formed a basis for the understanding of important relationships in nature. Towards the end of the nineteenth century soil science developed as an independent subject. Gradually it became possible to draw conclusions about production capacity based on more or less exact knowledge.

The growth potentials of plants are determined by climatic and edaphic factors. We can therefore distinquish between the site quality rating, including both these factor groups affecting a place, and the soil rating. The term soli-bonitati-metri (abbreviation: solbonmetri) is used as a name for the line of research realization of numerical expressions for the production capacity of different soils (LÅG 1968). In addition to the two mentioned rating systems, there is a third which is used when areas have to be interrelated, for example in connection with land reallocation.

The effects of different soil factors are discussed in general plant ecology literature. It is interesting to note that a textbook based on ecological principles, written by a Scandinavian scientist, was published in 5 editions during the period 1925—1957 (LUNDEGÅRDH 1957).

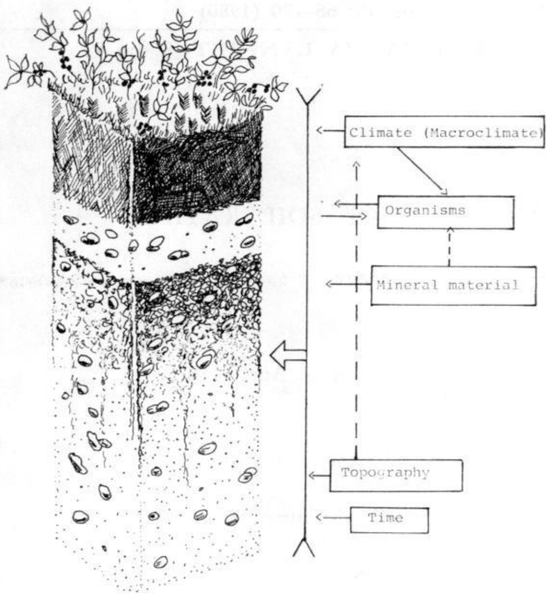

Fig. 1. Schematic presentation showing the influence of soil-forming factors.

Different groups of growth factors

Both the climatic and the edaphic growth factors can be divided into subgroups.

Plant growth is strongly influenced by temperature. The distribution of plant species as well as production of plant material are, to a great extend, dependent on this climatic condition.

In Fennoscandia altitude and latitude form the limits of very many plant species. Temperature is the most important factor in determining these distributions. The mean temperature decreases by about 0,6 °C per 100 m increase in elevation above sea level. With rising latitude there is also a decrease in the temperature. However, there are great differences between the oceanic climate along the Norwegian coast and the more continental climate further east.

The temperature factor does not have the same effect on all plant species. Ripening of seeds in particular demands minimum temperatures. The vegetative development may often continue normally even if the temperature is lower. Therefore, there are clear differences between the possibilities for small-grain cultivation and for fodder production. Favourable hay production may be possible in districts where low temperatures prohibit small-grain growing. An adequate water supply is very important for meadow plants. It has been stated that the fodder production in districts with adequate humidity will be approximately directly proportional to the number of days with a mean temperature higher than +5 °C (Bryson 1974). Some Norwegian publications of interest in this connection are referred to by Låg (1979).

The climatic factors of light and wind have an important effect. In the northern parts of Fennoscandia with intense light during the summer, the plants manage with a somewhat lower temperature than further south.

In addition to the direct influence of climate on the plants, it also has an indirect effect via its influence on the soil properties. Fig. 1 includes a schematic representation of the relationships between climate, soil and vegetation.

Influence of some soil factors on site quality

Survey

The soil quality class is influenced by a great number of factors. They are often divided into two main groups: chemical and physical soil factors. The most important chemical factors are related to the supply of nutrients of the plants. Soil water, texture, structure, temperature, and properties of the soil air are counted as the main physical factors. Many authors have also specified a group of biological factors. Other classification schemes place, for example, water supply of the plants as a special group beside the climatic and edaphic factors.

Such theoretically founded groupings of the growth factors are of importance to obtain an outline of the problems. They are, however, of less help in deciding the site quality class of a certain area. In such cases the use of numerical expressions would be desirable to investigate differences in each of the growth factors influencing the plants. However, it will probably take a long time before a thorough understanding, even of the most important growth factors, is obtained. In the work on estimation of the effect of the edaphic factors, we must start by using simple, easily determinable soil criteria. As an exact measure of the site quality class itself, we can use the capability of the area to produce plant material. But this property is not easy to determine precisely, either.

Many different, more or less ordinary systems for investigation of soil properties in connection with site classification have been proposed (see e.g. NIKLAS 1932, BERNSTORFF 1955, 1957, ROTH 1956, ROTHKEGEL 1959).

Among special systems, it is of some interest to note the so-called Storie index (STORIE 1950). The relative value of an area for forest production is determined by calculating the product of factors for: 1) depth and texture of the soil, 2) permeability, 3) chemical properties, 4) drainage, and 5) climatic factors. The value of each factor is expressed as a percentage of the most favourable case. For example, the STORIE-index will be 64 when the value of the 5 factors are 80 %, 100 %, 100 %, 100 %, and 80 %. When the area is estimated for purposes other than forestry, other specification factors are used. By such a multiplication of many factors, the calculated site class value may be too low.

A somewhat similar principle has been tried in Canada (BROWSER and MOSS 1950), using multiplication of 7 factors in all. Both these special systems have only been applied locally.

By soil mapping in the USA has been used a numerical attempt to state the plant producing capacity of the various soil series, when the areas are used for different plant species. This is an exact and easily understandable form of soil rating.

Foresters have to a certain extent, been estimating the future increment potential of the trees of particular areas on the basis of the properties of the ground cover vegetation. Site classification based on CAJANDER's forest types (see e.g. CAJANDER 1913, CAJANDER and ILVESSALO 1922) should be remembered. The expression solum: distributio plantarum has been introduced for the line of research into the effects of the soil factors on the distribution of plant species and plant communities (LÅG 1974). The prolonged plant material production of forests can be determined in a simple way by measurement of annual growth rings. Variation in increment because of changes in weather from one growth season to another, may be evened out by measuring the annual rings covering a long period, e.g. 10 years. It has often been easier to determine the site class of forested areas than of cultivated land.

GLØMME (1932, p. 284—285) planned to evolve a soil rating system based on humus investigations in forests. Unfortunately, bad health prevented him from carrying on with this research.

Site classification of peatland for cultivation or forest production has to a great extent been built on estimation of the vegetation. Many Nordic scientists have made valuable contributions to the elucidation of these problems.

The site quality classification of cultivated areas attemps to make use of observations of so-called type plants, too. Weed flora are being investigated in connection with this (see e.g. PETERSON 1930).

Some Norwegian investigations

A comprehensive investigation on forest soils in Norway was started in 1954. The soil science department of the Agricultural University of Norway and the National Forest Survey have worked together on elementary registrations of soil conditions in productive forests. Site classi-

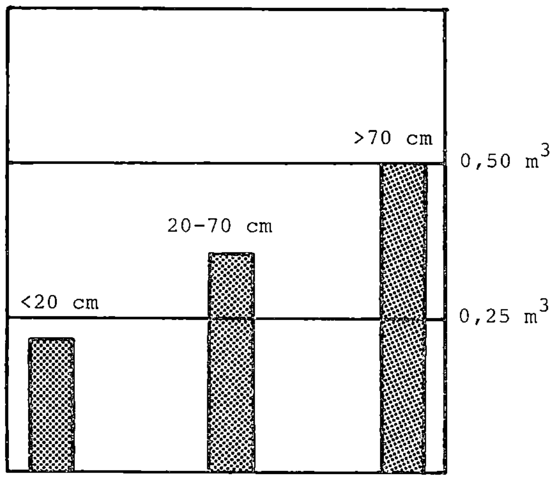

Fig. 2. Annual normal production in cu.m. per 1 000 m², on soil material of different depth in Agder counties, Norway. The comparisons were based on a little over 7 000 sample plots.

fication on the basis of increment of the trees was previously included in the work of the National Forest Survey.

A series of soil properties easily evaluated in the field was noted. Gradually, the registration

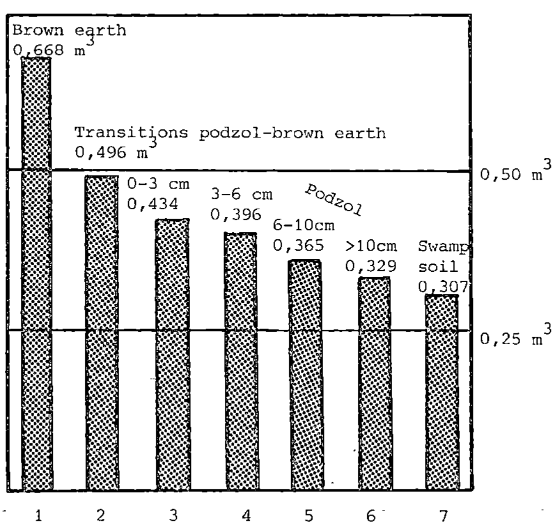

Fig. 3. Annual normal production in cu.m. per 1 000 m², on various soils in Hedmark county, Norway. The comparisons were based on a little more than 27 000 sample plots.

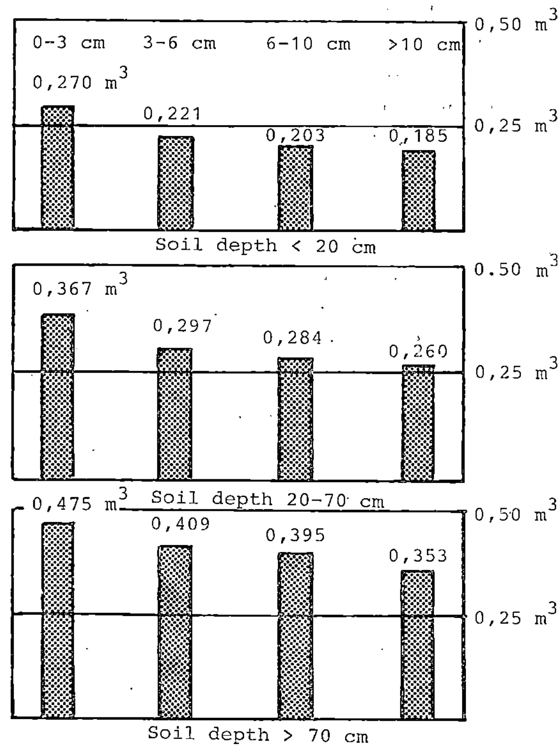

Fig. 4. Annual normal production in cu.m. per 1 000 m², on soil material of different depth and with various thickness of humus layer, North-Trøndelag county, Norway. The comparisons were based on nearly 11 000 sample plots.

was extended by including, e.g. collection and analysis of humus samples. Here we shall consider the relationships between a few soil properties and the increment of the trees.

Great parts of Norway have such a sparse cover of soil material over the bedrock that the potential for plant production is strongly limited. As an example of the influence which this factor has on the site quality, Fig. 2 shows the results of investigations in the southern part of Norway where the soil cover is especially scanty (LÅG 1967).

The registrations only include productive forests, i.e. forests with an annual normal increment of more than 1,2 m³ per hectare. If unproductive land with some trees had been included in the investigation, the differences between various depth classes would have been considerably greater.

Fig. 3 shows a clear relationship between main soil types and increment. The average for more than 100 000 observations of over 50 000 km² of forest investigated in the period 1954—1965, showed production of about 80 % for transition areas from brown earth to podzol, about 60 % for podzol, and about 50 % for swamp soil, when the production for brown earth is set to 100 %.

A relationship between thickness of humus layer and increment of the trees is indicated in Fig. 4. In a cool and humid climate, which is normal in Norway, the increase in humus depth correlates with decrease in production.

Fig. 1 shows that there is not a mutual interaction between soil and vegetation, and that the climate influences both of them. There is simple causal relationship between humus thickness or profile type on one hand and increment on the other, but a strong correlation may still occur. The depth of soil material is a primary property in the principle, and therefore we have a direct causal relation between this soil factor and the plant production.

In Norway, research on the question of site quality in relation to soil properties will continue. The problems connected with solbonmetri seem to draw considerable attention. It is important to be able to determine the quality class of an area as accurately as possible. Further, an elucidation of these difficult problems may be of importance for the selection of methods for soil investigations.

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ANNALES AGRICULTURAE FENNIAE, VOL. 19: 71—80 (1980)

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FERTILIZER APPLICATION AND GROUND WATER POLLUTION

KJELD RASMUSSEN

RASMUSSEN, K. 1980. **Fertilizer application and ground water pollution.** Ann. Agric. Fenn. 19: 71—80. (R. Vet. Agric. Univ. DK-1871 Copenhagen V., Denmark.)

The question whether the increased amounts of fertilizer used may cause ground water pollution is discussed. The aim is to present these problems in relation to Danish conditions and therefore the discussion is based mainly on the results of Danish investigations.

It is concluded that in Denmark the only plant nutrient which may pollute the ground water is NO_3^-. The risks that this will happen will vary from the eastern to the western parts of Denmark since the two regions differ with respect to climate soils and hydrologi as well as with respect to farming methods. Under certain conditions pollution with NO_3^- may take place locally.

Index words: Water pollution, nutrients in soil, leaching, denitrification, nutrient balance in plant nutrition.

INTRODUCTION

In Denmark as in many other countries it is discussed if the use of increasing amounts of fertilizers may give rise to ground water pollution. The risks depend not only on the amounts of fertilizers applied, but also on farming practices and on environmental factors such as climate, soils and hydrology. Therefore, the problems may vary from one country to another. In spite of such differences there will also be some similarities. Therefore, it is hoped that the following considerations will not only present the problems as they may appear from a Danish point of view but also, in a modest way, contribute to the discussions going on outside Denmark.

The amounts of fertilizers (F) and manure* (M) used in Danish agriculture

In Denmark the farmed area covers about 3 million hectares. A little more than 60 percent is used for small grains (mainly barley). Grass takes up nearly 25 percent and root crops (mainly beets) about 10 percent. The livestocks comprise at present somewhat over one million of milking cows and a similar number of heifers and calves. To that comes 5—6 millions of hogs. The amounts of plant nutrients applied in manure and fertilizers appear from Table 1.

* By manure (M) is here and in the following understood the combined amounts of liquid and farm yard manure.

Table 1. Fertilizer consumption in Denmark (HENRIKSEN 1973).

Year	N kg/ha/a			P kg/ha/a			K kg/ha/a		
	F	M	total	F	M	total	F	M	total
1901—05	0	21	21	1	7	8	1	26	27
1941—45	13	33	46	1	11	12	16	48	64
1961—65	47	46	93	17	16	33	47	54	101
1965—66	64	51	115	18	18	36	51	59	110
1969—70	91	48	139	19	17	36	51	52	103
1973—74	124			23			61		
1974—75	103			17			46		
1975—76	116			19			49		
1977—78	124			20			49		

F = fertilizer, M = manure

Figures for earlier years are also included. The figures are average amounts in kg per ha.

In supplement to the figures in Table 1 it should be mentioned that the consumption of fertilizer-N in 1979 as an average was 130 kg/ha (OLESEN 1979) and — more important — that SKRIVER (1980) on the basis of KJELLERUP and SØNDERGAARD KLAUSEN's (1975) investigations has calculated the amount of manure-N to have been 84 kg/ha in 1977. For the years before 1970 the figures in Table 1 have been taken from a commission report (FORURENINGSRÅDET 1971) which was worked out ten years ago, but in the same years LINDHARD (1970) calculated the amount of manure-N to be 66 kg/ha. ANDERSEN (1979) bases his calculations of manure-K on the estimate that better storage conditions imply that losses of manure-K now make up only 30 percent against earlier 35 percent. The differences between the estimates illustrate the uncertainty of the figures.

Plant nutrient balances for an average Danish soil

For plant nutrients other than N, ANDERSEN (1979) have calculated detailed balances for an average Danish soil. The following figures are taken from ANDERSEN's paper.

ANDERSEN figures are based on investigations and calculations carried out recently. With regard to precipitation the measurements have been made by JØRGENSEN (1978) and HOVMAND (1977). Amounts taken up directly from the atmosphere are not included. Losses by leaching was calculated from measurements and analyses of drain water carried out by HANSEN and PETERSEN (1975) (macro nutrients) and by JENSEN (1978) (micro nutrients). The calculations was based on the assumption that only half of the leaching water entered the drains.

Losses by crops were calculated from official statistics concerning yields and from analytical data. Calculations of plant nutrients in manure were based on the assumption that 20 percent of the P and 30 percent of the K in the crops

Table 2. Plant nutrient balances for an average Danish soil (ANDERSEN, 1979).

Element	P	K	Ca	Mg	S	Mn	Cu	Zn	Mo	B
	$kg \cdot ha^{-1} \cdot year^{-1}$					$g \cdot ha^{-1} \cdot year^{-1}$				
Added with										
precipitation	0	3	9	3	15	100	18	150	?	30
manure	22	58	27	9	13	550	150	450	2	55
fertilizers and lime	20	54	240	5	21	207	311	45	1	81
total	42	115	267	17	49	857	479	645	3	166
Lost										
with crops	18	80	18	9	15	400	30	250	3	60
by leaching	0	2	254	16	56	72	6	88	?	18
total	18	82	272	25	71	472	26	338	3	78
Added — lost	24	35	—5	—8	—22	385	443	307	0	88

harvested was lost during handling of the fodder and storage of the manure. Gains of nutrients from »outside», e.g. in concentrates, as well as losses connected with sale of animals and plant products were taken into account. Thus, the figures may represent the best estimates of the average nutrient balances that can be obtained at present.

Table 2 shows that Danish soils on an average has a positive balance with regard to several plant nutrients, but it also indicates that in general no serious losses of these plant nutrients occur by leaching. In the drain water Ca makes up the main part of the cations. The high Ca content is due to liming since most Danish soils are limed to pH-values higher than 6. It presents no problems with regard to drinking water quality. The small amounts of other plant nutrients found agree well with our present knowledge of the soil chemistry of these elements. Even if the average figures must include considerable variations it seems safe to conclude that the elements concerned do not present serious risks of ground water pollution.

Nitrogen balances of Danish soils

Nitrogen may cause more problems than the plant nutrients mentioned above. Under the conditions prevailing in Danish arable soils NH_3 and NH_4^+ will only exist at low soil temperatures. At higher temperature it will be subject to nitrification into NO_3^-. Since NO_3^- forms no insoluble compounds in soils and is not absorbed on soil colloids it will be leached in periods with surplus precipitation, in Denmark mostly during the winter.

The leaching of NO_3^- does not only cause an economic loss to the farmers, it may also cause a content of NO_3^- in the ground water. WHO norms recommend that drinking water should not contain more than about 10 ppm NO_3^--N although the double content may be accepted. It can not be excluded that such NO_3^--concentrations may appear in the leaching water.

ANDERSEN does not include N in his calculations because of the uncertainties connected with N-balances for soils. Several parts in the N-balance of soils are indeed open to question. Thus, the amounts of NH_3 which are lost by evaporation under ordinary farming practice can only be roughly estimated. Also the amount of atmospheric N_2 fixed by microorganisms is not well known. It is generally assumed that free-living microorganisms will only assimilate modest amounts ($\leq$ 10 kg N/ha/year). On the other hand microorganisms in the rhizosphere of higher plants (mainly leguminoses) may assimilate more than 100 kg N/ha/year. However, at present Danish grass fields receive so much fertilizer-N that N_2-fixation by leguminoses is suppressed.

In ordinary soils a loss of gaseous N in forms of NH_3 will only take place during application of manure. But even in well-drained soils anaerobic conditions may prevail in microregions characterized by high biological activity. In these localities denitrification may take place and the result will be a loss of N as N_2 and N_2O. Also the size of this loss is open to question.

The content of inorganic nitrogen, NO_3^--N in the soil will be influenced by its humus balance. A decline in humus content may lead to an increase in NO_3^--content and vice versa. The contents of humus-N may be 100 times the amounts of N annually taken up by crops. Therefore, relatively small changes in the soils humus content may completely alter the soils balance with regard to inorganic N.

ASLYNG (1978) and LINDHARD (1970) have set up N-balances for an average Danish soil. The results are shown in Table 3.

The figures in Table 3 refer to different years and therefore reflect different conditions. In spite of this the estimates for N-fixation and for loss of N to the atmosphere (denitrification) are of about the same sizes. The differences seen is in

Table 3. N-balances for an average Danish soil. Kg N/ha/year.

	LINDHARD (1970) *)	ASLYNG (1978)	Other data
To the field:			
from atmosphere (microorg.) ...	33	28	
with precipitation	15	12	12 (JØRGENSEN, 1978)
» manure	66	45	84 (SKRIVER, 1980)
» fertilizers + seeds	66	115	130 (OLESEN, 1979)
total	180	200	
From the field:			
to crops	112	130	
by leaching	18	27	
humus formation	33		
denitrification from top soil	15	43	
total	178	200	

*) Based on figures for 1965/66.

agreement with the theory that use of more fertilizer-N may hamper N-fixation and enhance denitrification.

Recent assessments of N-losses by denitrification

Investigations and measurements indicate that LINDHARD and ASLYNG's estimate reflect the amount of NO_3^--N lost by denitrification under Danish soil conditions quite well. KOLENBRANDER (1975) for instance came to similar figures when reviewing field- and lysimeter experiments. HVELPLUND and ØSTERGAARD (1980) carried out field experiments where the N-uptake by crops as well as the NO_3^--content of the soil were studied. They found that 40—50 kg NO_3-N/ha disappeared from the soil in a way that could not be accounted for. Laboratory experiments showed that denitrification might take place at a rate of 2—4 kg N/ha/week when NO_3^- was added to samples of the soil used in this experiment. Accordingly, it was concluded that denitrification accounted for a substantial part of the loss of NO_3^--N mentioned above.

In their studies, HVELPLUND and ØSTERGAARD made use of the fact that the transformation of NO_3^- to N_2 goes through N_2O and can be stopped at this stage. The amount of N_2O formed was measured by gas chromatography. In later years this technique has been used in several investigations and it is to be expected that it will improve the knowledge of the factors which govern denitrification processes and -rates. For instance HVELPLUND and ØSTERGAARD found that denitrification nearly stopped at temperatures below 10 °C. Another important factor is the oxygen tension in the »active domaines» of the soils where the denitrification takes place. Recently CHRISTENSEN (1980) has demonstrated the importance of this parameter. He reviewed results from denitrification studies carried out under laboratory conditions. The denitrification rates obtained in these experiments varied several orders of magnitude, but rates of about 0,1 μg N/g soil/hour were common. In his own experiments Christensen obtained similar denitrification rates. In accordance with the results reviewed he found that denitrification rates increased with water content of the soils. High rates were found when the soil contained less than 3 vol percent air and when the soil air was low in oxygen. Investigations on denitrification in relation to soil parameters are also carried out by LIND (1980).

The refined methods which are now at hand for measuring soil factors and their influence on denitrification may soon give us better knowledge about the denitrification that actually takes place in the field under different conditions. At present it seems that it would not always be safe to rely on denitrification in the top soil as a mean to keep ground water free of NO_3^-.

One more parameter in the N-balance of soils is rather unknown, namely the soils humus-balance. ASLYNG (1978) and LINDHARD (1970) suppose that this balance generally is positive due to increasing dressings of fertilizers and

Table 4. Losses of NO_3^--N with drain water. Kg N/ha/year.

Area	percent clay in soil	crop 1971	crop 1972	crop 1973	Added in fertilizer-N 1971	Added in fertilizer-N 1972	Added in fertilizer-N 1973	N found in drain water average	Run off as drain water average mm/year
3,8	13	B	P	W	100	0	100	23,0	93
17,9	7	L	B	B	120	75	100	36,5	143
10,0	11	R	B	B	110	110	0	24,1	135
9,0	10	B	B	R	120	110	160	18,7	80
9,5	11	R	B/R	B	155	100/150	100	14,6	120
3,0	15	B	B	B	100	100	100	21,7	118
4,0	12	B	B	B	105	105	105	14,9	86
14,5	11	B	B	B	120	120	100	16,4	113
10,0	13	P	B	B	140	100	100	32,2	216
22,5	13	W	B	G	130	100	120	16,6	102
10,0	12	G	W	B	140	160	110	18,3	85
10,0	10	W — R — B — G			(70—140)*)			9,1	62
9,0	10	B/R	B	R/G	50/100*100		100/200*)	16,9	72
5,5	15	B	B	Cl	100	200	200	22,4	160
Average					(123)	(104)	(115)	21,1	117

*) manure
B = barley, P = peas, W = wheat, L = lucerne, R = root crop (beets), P = poppy (seed), G = grass, Cl = clower grass.

increased crop yields. On the other hand, an increasing percentage of the arable land in Denmark is used for grain production and this will generally have a depressing effect on the humus content. Therefore, it will be most safe to conclude that the humus content in Danish soils as a whole is at best constant.

Thus it seems that an average Danish soil each year may loose a substantial amount of nitrogen — say 50 kg of NO_3^--N — by leaching. Analyses of drain water confirm this figure.

Nitrate in drain water

In Denmark very few systematic investigations on NO_3^- loss with drain water had been carried out when pollution problems came into focus ten years ago. Consequently such measurements were performed on several localities (Hansen and Pedersen, 1975). Average results from the 3 years 1971—73 incl. are shown in Table 4. From Table 4 may be calculated that as an average for the 3 years and for all localities the drain water contained 18 ppm NO_3^--N. It can be estimated that the amount of drain water collected (≈ 117 mm/year) only represents about half of the water annually leaching through the soils. Therefore the actual loss of NO_3^--N must have been about 40 kg/ha/year.

From place to place large variations were found even if all the soils represent moraines with a sizeable clay content. Similar losses of NO_3^- were registered in lysimeter experiments carried out during the years 1962—71 (Lindhard 1975). Some of the results are shown in Table 5. The last column in the table represents average values for the ten years in kg N/ha/year. Also some field experiments carried out at Sdr. Stenderup 1973 and 1974 should be mentioned. The results appear from Table 6 (Kjellerup, 1975).

The experiments have been continued and in a recent paper Kjellerup and Dam Kofoed (1979) present the results obtained in the following 3 years. However, in this subsequent period the experiments conditions were changed. In the first year precipitation was very scarce and in the following two years crops other than barley were grown.

In this experiment also the amounts of N contained in the crops were determined. It

Table 5. N-balances for 3 soils during 10 years, g N/m².

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	Total
Sandy loam:											
N in dry matter	19,2	17,0	19,3	7,8	9,2	8,1	7,4	6,6	7,6	8,0	110,2
N leached	2,4	5,6	4,0	7,4	6,1	4,5	4,7	6,2	3,4	4,8	49,1
removed	21,6	22,6	23,3	15,2	15,3	12,6	12,1	12,8	11,0	12,8	159,3
supplied	15,9	15,9	16,0	7,4	6,4	6,9	6,6	6,4	7,4	8,0	96,9
N supply from soil	5,7	6,7	7,3	7,8	8,9	5,7	5,5	6,4	3,6	4,8	62,4
Loam:											
N in dry matter	21,1	15,7	17,6	8,8	8,3	8,1	8,1	7,5	8,2	8,5	111,9
N leached	2,6	3,6	3,4	7,1	6,1	4,3	2,7	5,0	3,0	3,6	41,4
removed	23,7	19,3	21,0	15,9	14,4	12,4	10,8	12,5	11,2	12,1	153,3
supplied	15,9	15,9	16,0	7,4	6,4	6,9	6,6	6,4	7,4	8,0	96,9
N supply from soil	7,8	3,4	5,0	8,5	8,0	5,5	4,2	6,1	3,8	4,1	56,4
Sand:											
N in dry matter	16,6	15,1	14,3	6,6	7,8	6,1	6,1	4,7	5,8	5,7	88,8
N leached	2,6	2,7	3,0	3,6	2,7	3,5	2,6	6,7	2,9	4,1	34,4
removed	19,2	17,8	17,3	10,2	10,5	9,6	8,7	11,4	8,7	9,8	123,2
supplied	15,9	15,9	16,0	7,4	6,4	6,9	6,6	6,4	7,4	8,0	96,9
N supply from soil	3,3	1,9	1,3	2,8	4,1	2,7	2,1	5,0	1,3	1,8	26,3

appears from the Table 6 that leaching of NO_3^- was nearly independent of the amounts of N applied and further that the N-balance of the soils in all plots were negative. This illustrates the importance of the humus fraction for content of inorganic N in the soils and for the leaching of NO_3^-.

Fig. 1 is taken from KJELLERUP and DAM KOFOEDS paper (1979). It shows that by using moderate gifts of fertilizer-N will the crops take up nearly all the nitrogen applied. However, if the amounts of N applied are increased above a certain level does this relationship no longer hold. Incremental additions of N may then result in a marked increase in NO_3^--leaching. The amount of N, which can be applied before this will happen depends on the crop grown (compare Fig. 1) but it also depends on the state of crop. Thus, BENNETZEN (1978) found that 148 kg NO_3^--N per ha was lost by leaching from an unirrigated grass field on a coarse sandy soil after the very dry summer of 1975.

Table 6. N-balances for a loam soil, cropped with barley. Kg N/ha/year.

N in added fertilizer		N in crops harvested		N in drain water	
1973—74	1974—75	1973—74	1974—75	1973—74	1974—75
0	0	54	58	12,5	15,0
55	55	80	89	13,4	17,6
110	110	98	110	16,0	22,4
165	165	104	114	19,1	31,7

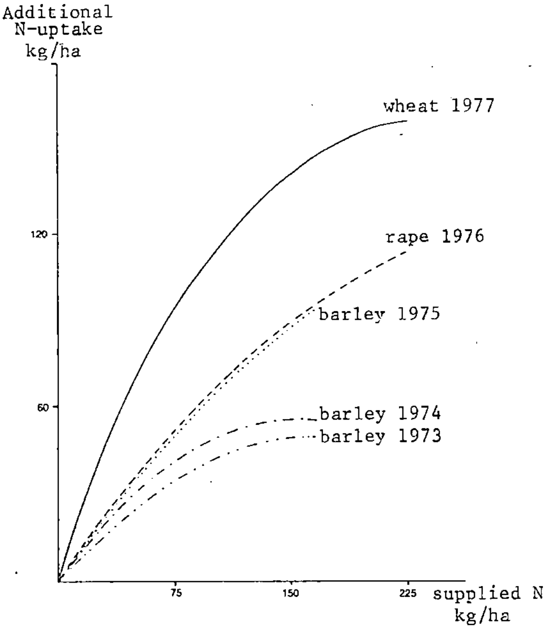

Fig. 1. Additional removal of nitrogen in the crop. Sdr. Stenderup 1973—77.

Comprehensive investigations on N-uptake and NO_3^--movements in soil profiles have been made by BENNETZEN (1978). The measurements were carried out on a coarse sandy soil as well as on a clay loam. With respect to leaching of NO_3^- from fields cropped with barley, BENNETZENS results agree with the figures presented above. On the sandy soil his studies were extended also to grass fields and for this soil he also studied the effect of irrigation. His investigations, therefore, comprised several factors, which highly influence NO_3^--leaching and have given valuable results.

Several more Danish investigations in this line might be referred to, but the ones mentioned above are sufficient to show that denitrification does not remove all surplus N in the soils and that substantial amounts of NO_3^- are leached to layers below the root zone of crops.

The rather coarse sandy soils in West Jutland have not been found well suited for experiments involving measurements of drain water and collection of representative drain water samples for analyses. Other factors being equal, one would not expect smaller NO_3^--leaching from these soils because of their lower water holding capacity and because they probably offer less favourable conditions for denitrification. However, also other factors must be taken into account when discussing the risks for water pollution in different parts on Denmark.

Regional differences in respect to hydrology and precipitation in Denmark

Fig. 2 (ASLYNG 1976) shows the mean annual precipitation in different parts of Denmark. However, the Danish Meteorological Department has recently announced that the published figures for precipitation are low by 16 percent relatively. No correction has been applied to the figures in Fig. 2. However, Fig. 2 shows that the western part of Denmark receives more precipitation than the eastern part. It is in the

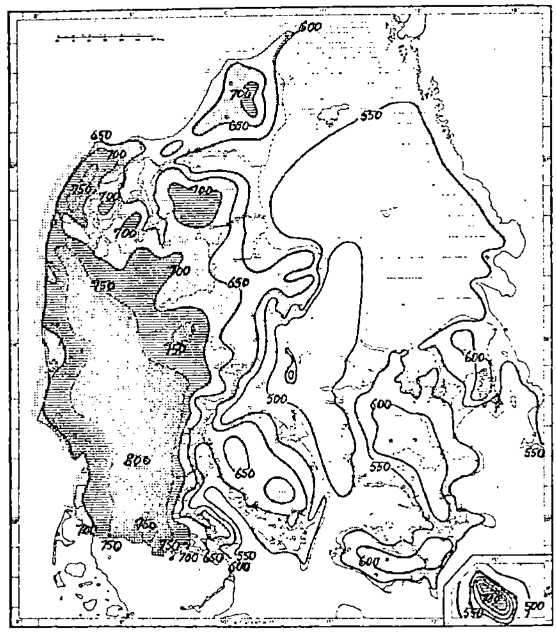

Fig. 2. Mean annual precipitation 1931—60. (Danish Meterological Department).

same western region we find the more sandy soils. South and West Jutland were not covered by ice under the last glaciation and the soils have been formed partly on meltwater sand deposited during the last glaciation (Weichsel), partly on sandy moraines and meltwater deposits from the glaciation before (Saale). These old landscape elements have been very effectively levelled, e.g. by gelifluction due to the arctic conditions prevailing at the Weichsel glaciers. South and West Jutland therefore have a level landscape. The young (Weichsel) landscape in North and East Denmark shows a much more varied topography and in many places Weichsel moraines contain 15—20 percent clay. Accordingly most of the region is characterized by loamy soils.

Due to the higher water holding capacity of the soils it has been estimated that the actual evapotranspiration is higher in the Eastern region ($\approx$ 400 mm/year) than in the Western ($\approx$ 350 mm/year). Therefore, leaching will be much more marked in West than in East, and on the sandy plains of Western Jutland we will often find the ground water near to the surface while in East Denmark it may be found under thick layers of clayey glacial deposits. Where the leaching water must pass such layer it may take long time before it reaches the ground water. Consequently, possible ground water pollution will be apparent only after some delay. On the other hand it may have a longer lasting effect than in West Jutland where percolation to ground water takes place rapidly.

Differences in farming in the two regions

While the production of hogs for bacon is rather evenly distributed over the country, most of the cattle is found in the western parts. Therefore, it is also in that part of Denmark that fields with grass and sugar beets are most common. These crops are fertilized with heavy dressings of nitrogen. In two counties in this region (Ringkøbing amt and Ribe amt) the consumption of fertilizer-N in 1977 went up to 140 kg/ha. In two other counties, typical for East Denmark (Vestsjællands amt and Storstrøms amt) only 109 kg N/ha was used that year (SKRIVER 1980). Also the amounts of N in manure were different: 89 kg/ha and 50 kg/ha respectively (SKRIVER 1980). Thus, in 1977, the farmers in West Jutland applied as an average 229 kg N/ha and their counterparts in East Denmark only 159 kg/ha. It is obvious that these differences in farming practice must influence the N-balance of the soils.

Different cropping systems in relation to loss of NO_3^- by leaching

It is well known that the use of annual crops with a short vegetative period, e.g. barley, often will lead to leaching of NO_3^-, especially if the soil is rich in decomposable organic material. NH_3 formed by decomposition of organic matter may in the autumn be subject to nitrification and then be leached during the winter (KOLENBRANDER 1975).

In some years soil temperature may allow nitrification to go on until December. It is not surprising that substantial amounts of NO_3^- may then be leached.

It is also well known that crops which continue to grow until the winter, especially grass crops, will take up the NO_3^- formed. From most grass fields literally no NO_3^- is lost by leaching. In this connection it may be mentioned that HVELPLUND and ØSTERGAARD (1980) have demonstrated that leaching of NO_3^- may be effectively hindered, at least on clayey soils, if a suitable crop, e.g. rape, is sown immediately after the grain crop (barley) has been harvested. The green crop of rape may then be ploughed under during the winter and a new crop of barley sown in the spring.

From what is mentioned one might conclude that extensive use of grass in the crop rotation will lead to diminished losses of NO_3^- by leaching. However, when the pastures are ploughed and used for grain crops, mineralization of organic materials will cause extraordinary amounts of N to be liberated. This process is rather uncontrollable and may go on also outside periods when grain crops, like barley, take up NO_3^-. The same apply to the manure, of which plentiful amounts are at hand on the farms in question (KOLENBRANDER 1975). Moreover, since the amounts of N liberated from such compounds depends on the years climate, farmers will often add fertilizer-N in bigger amounts than necessary.

The conclusion seems to be that the heavier dressings of N applied in the Western parts of Denmark sooner or later must result in an increased loss of NO_3^- by leaching. However, since also the surplus of precipitation is bigger, this does not necessarily mean that the NO_3^--concentration in the percolating solution will be higher here than in the eastern parts of the country.

Even if this may apply for the region as a whole one cannot exclude the risk for local ground water pollution. This may for instance happen where farmers keep extraordinary large livestocks, in most cases hogs, which are kept mainly on purchased fodder. On such farms so large amounts of manure will have to be disposed of, that arrangements with helpful neighbours may be necessary. The official view is at present that manure should not be applied in bigger amounts than equalling 200 kg N, 80 kg K and 50 kg P per ha per year. If these limits seem restrictive it must be remembered that the use of big amounts of manure as a rule does not exclude that some fields in the rotation will be given mineral fertilizers. It must be expected that this type of farming under »favourable» hydrological conditions may cause local ground water pollution.

Denitrification in underground layers

In the considerations it has so far been implied that the water percolating the soil will undergo no change on its way from the root zone to the ground water. However, it has long been known that where the ground water is covered by thick layers of clayey glacial deposits it is nearly always free of NO_3^- (ØDUM and CHRISTENSEN 1946).

CHRISTENSEN (1970) advanced the theory that when water with dissolved NO_3^- have to pass such layers NO_3^- will be reduced by Fe^{++} which are present under the anaerobic conditions. The theory was supported by the fact that ground water may contain NO_3^- in places where the protective clayey layers are replaced by coarser material which gives better access to oxygen. Full documentation has been obtained by LINDS and BRINK PEDERSENS investigations (1976). By studying samples drilled up from underground layers at different localities they found that layers which contained reactive Fe^{++}, never contained NO_3^-.

Also BENNETZENS results (1978) indicate that NO_3^- reduction takes place in clayey soils underground layers.

LIND and BRINK PEDERSEN further demonstrated that N_2 and N_2O was evolved when NO_3^- was added to samples of such underground layers. It is supposed that this reduction may take place chemically as well as microbiologically.

It is fortunate that this natural ground water protection takes place in many regions, especially in the eastern parts of Denmark. But it may be questioned if this protection will hold if the reduced layers during long periods are percolated by water with a high content of dissolved NO_3^-. However, in spite of its NO_3^- content it is uncertain to what extent such a solution will oxidize the underground layers. In addition to NO_3^- it also contains small quantities of reducing substances, for instance dissolved organic matter (KOLENBRANDER 1975, PETERSEN 1976). The data presented by KOLENBRANDER indicate that the reduction capacity of the leaching water, as expressed by its chemical or biological oxygen demand, will only be sufficient to reduce small amounts of NO_3^- ($\leq$ 5 mg/l NO_3^--N). However, one should not dismiss the possibility that different results might be obtained for other soils and under other conditions. This question seems to deserve closer investigation.

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ANNALES AGRICULTURAE FENNIAE, VOL. 19: 81—84 (1980)

Seria AGROGEOLOGIA ET -CHIMICA N. 99 — Sarja MAA JA LANNOITUS n:o 99

LONG-TERM CHANGES OF FOREST SOILS

Tryggve Troedsson

Troedsson, T. 1980. **Long-term changes of forest soils.** Ann. Agric. Fenn. 19: 81—84. (Department of Forest Soils, Univ. of Agric. Sci. S—750 07 UPPSALA, Sweden.)

It is important for soil scientists to follow the changes of the soil conditions regarding both pollution and the ordinary use of soils in forestry, agriculture, etc.

As an example of these problems the acidification of the soils has been discussed. The relationship between the pH and the age of the tree shows a decreasing pH in older stands. The tolerance to acidification of the soils can be calculated based on more than 80 000 sample plots.

Index words: Soil sampling, acidification, pollution tolerance of soils.

INTRODUCTION

Soil formation is conditioned by a number of factors, among which parent material, climate, living organisms, relief and the timefactor are most significant. These factors have been studied for many years and today we have good knowledge of the soil-forming processes.

The time factor and its influence on soil-forming processes belong to one of the most complicated problems facing soil scientists.

Introduction of modern techniques, fertilization and other methods in forestry and agriculture have up till now been referred to the yield of the soil. The effect of the productivity of the soil with time has, however, been neglected. The reason for this development is due to two facts; one being that soil processes are very slow, and the other that it is difficult to measure soil changes during, for instance, a ten-year period. As a rule it is too short a time to measure soil changes.

CLAIMS ON METHODS TO MEASURE SOIL CHANGES

In a few years it will be very important to measure all changes of the soil status. The increasing pollution of plants and soils will place demands on methods to follow the development of the soils. In some respects it has been possible to measure changes in the development of soils.

Today we know, for example that heavy metals have increased in our cultivated soils.

However, traditional analytical methods are still unable to measure the acidification of soils in relation to acid precipitation.

SOIL SAMPLING

In this respect one of the fundamental problems is the procedure for soil sampling (Troedsson and Tamm 1969). It is important to consider not only the variability of the soils but also the time elapsed after soil sampling until the chemical analysis is carried out. The following figure is given as an example (Dehlén 1974).

It is wellknown that the same circumstances are more or less valid also for K, PO_4, Ca, etc. Consequently, it is very important to analyse the soil sample as soon as possible after collection. Otherwise it will poorly reflect the field conditions.

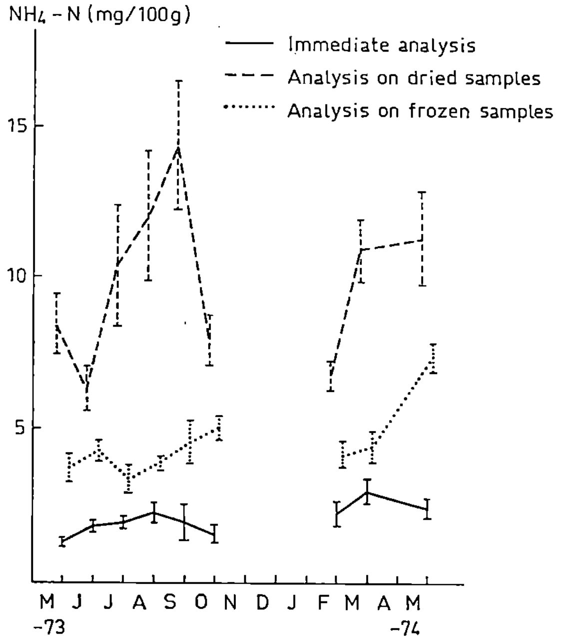

Fig. 1. NH_4—N in A_0-horizon (mg/100 g d.w. after R. Dehlén 1974).

Table 1. Relationship between age classes and pH in A_0-horizons on podzols in southern Sweden (Troedsson and Wiklander 1980).

Age classes	pH			
	Norway Spruce	n	Scots Pine	n
0— 20	4,12	253	4,01	167
20— 40	4,01	184	3,95	75
40— 60	4,01	319	3,89	125
60— 80	3,94	294	3,87	161
80—100	3,91	153	3,82	126
> 100 years	3,92	44	3,85	91

After these problems have been solved it is, however, impossible to return to the same sample plot after, for instance, a ten-year period in order to follow the development of the pH. In a forest soil the production of biomass during such a period will have caused an increasing adsorption of H+ in the A_0-horizon because the humus layer has become thicker. If the number of sample plots is very large it is possible to avoid these problems.

In connection with the National Forest Survey in Sweden a survey of forest site conditions has been carried out. In this comprehensive material it has been possible to make a selection of sample plots with forest stands of the same age class and with the same site factors. In Table 1, pH in the A_0-horizon has been investigated in selected material of this kind, for instance, the error of an increasing humus layer with age has been eliminated.

It is clear that the yearly biomass production gives an increasing H+-ion content in the humus layer. The statistical significance for decreasing pH with age is very high(***).

The decreasing pH in old forests (> 100 years) is due to the fact that the stands are thinned, which implies that grasses, etc., invade the soils.

The other question is how much of the pH is caused by the biomass and how much by the atmospheric deposition? At least we know that deposition is not especially high.

TOLERANCE OF SOILS TO CHANGES WITH TIME

The discussion above has introduced some of the problems involving measurement of changes in the soil over time. The question of the tolerance of the soils against pollution, etc., is of similar importance.

Local authorities are presently planning for coal-fired power stations, factories, etc., and are particularly interested in the expected acidification of the soils.

Between 1961—74 the above-mentioned soil survey has given about 150 000 sample plots, where the relationships between yield and site properties also have been studied (LUNDMARK 1974). This investigation has made it possible to classify the site properties with regard to the tolerance to acidification.

Mean values from about 80 000 plots are behind the observations in Table 2. The site properties are classified in different groups (vegetation, humus layer, thickness of soils, soil type, etc.). Each group may have up to ten classes. In Table 2 it has been necessary to pool many of the classes as otherwise the differences in tolerance would be too small.

The table is an example of how site properties can be arranged regarding the tolerance to acidification by deposition from factories, atmosphere, etc. in Swedish forest soils.

Table 2. The tolerance of soils to a acidification in relation to site properties and exchangeable cations (A_0-horizon; n = 2 500).

Site properties	Tolerance to acidification	Exchangeable metallic cations (me/100 g)	Cation exchange capacity (me/100 g)	pH
Pine forest	—	20	31	3,97
Broad-leaved trees	+	26	32	4,42
Thickness of A_0-layer				
0— 6 cm	—	19	28	4,23
> 6 cm	+	28	35	4,15
Thickness of soil layer				
<20 cm	—	18	29	4,07
>70 cm	+	24	32	4,20
Solid rock	—	19	30	4,03
Peat	+	34	38	4,08
Podsols	—	21	30	3,99
Dystric Cambisols	+	27	41	4,38
Stone-sandy soils	—	21	31	4,17
Fine sandy soils-clay	+	30	36	4,41
High freq. of boulders	—	22	32	4,13
Low freq. of boulders	+	26	40	4,22
Dry soils	—	17	29	3,94
Mesic-wet	+	39	40	4,13

+ = high
— = low

The tolerance of the soils to acidification also involves the need of liming to neutralize acid deposits.

Knowledge of the different soils in a region anables calculations to be made of the area of soils sensitive to acidification. This is very important for municipal planning.

DISCUSSION

In the situtation today, soils are being destroyed by pollution, acidification, heavy metals, etc. The use of soil in agriculture and forestry is also changing the soil status. Therefore in a long-term perspective the changes in soil must be carefully observed. The primary problem is to sample and analyse the soils in respect to the biological, physical- and chemical conditions in the fields and not after several months in the laboratory.

The soil sampling in the field must be made with statistical significance. It is not enough to analyse only one soil profile. Following this it is important to differentiate between natural changes (by the plants) and artifical deposits. There is a serious lack of suitable methods in this respect.

The tolerance of the soils to a certain type of pollution — as shown for acidification above — is one approach that can be used until better methods are obtained for application in soil research.

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Seria AGROGEOLOGIA ET -CHIMICA N. 100 — Sarja MAA JA LANNOITUS n:o 100

FERTILITY OF DIFFERENT MIRE TYPE GROUPS

LEILA URVAS, RAIMO ERVIÖ and SEPPO HYVÄRINEN

URVAS, L., ERVIÖ, R. & HYVÄRINEN, S. 1980. **Fertility of different mire type groups.** Ann. Agric. Fenn. 19: 85—91. (Agric. Res. Centre, Inst. Soil Sci. SF—01300 Vantaa 30, Finland.)

A soil survey material collected from natural peatlands was divided into six mire type groups on the basis of indicator plant species. The type groups in decreasing order of fertility were 1. fen-like, 2. herb-rich, 3. ordinary sedge, 4. small-sedge, 5. cottongrass and dwarf-shrub and 6. fuscum. The acidity of the peatlands increased by about one pH unit going from the fen-like to the fuscum type group. According to soil testing studies, contents of extractable calcium and total nitrogen fell as the mire type group worstened (Ca from 1149—157 mg/l, N from 1,94—0,70 %). Contents of extractable potassium and phosphorus, however, were fairly similar for all the mire type groups, and showed no tendency to vary with type. For the first three types the C/N ratio averaged 24, but increased through 41 for the small-sedge type group to 67 for the fuscum type group.

Index words: Mire type, extractable nutrients.

INTRODUCTION

When making agricultural soil maps, the Institute of Soil Science has classified the peats from mires into two groups: *Carex*-dominated and *Sphagnum*-dominated peats. Nevertheless, during sampling an attempt is made to describe the mire type, or at least the mire type group of each sampling site. For the purposes of this study, samples taken from natural peatlands in connection with soil mapping were all placed in one of six mire type groups. The aim of the study was to find out how reliably surveyers, using a classification designed only for practical use, and based on a few indicator species, were able to classify the peatlands. The second aim was to determine the nutrient levels of the different mire type groups.

MATERIAL AND METHODS

The material for study was collected from 851 sampling sites within 14 of the soil mapping areas of the Institute of Soil Science, and composed on a total of 2553 samples. Peat samples were taken from three layers: 0—20, 20—40 and 40—60 cm. The numbers of sampling sites in different areas were: Espoo 30, Jyväskylä 29, Kouvola 29, Lahti 29, Lohja 23, Pori 56, Porvoo 32, Riihimäki 52, Rovaniemi 268, Ruukki 167, Teisko 15, Tornio 46, Valkeakoski 28 ja Vammala 47.

The mire type of the sampling site was determined according to a classification based on the work of HUIKARI (1952), who later adapted the method mainly for use in practical forest drainage (HUIKARI et al. 1963). In the modified classification, peatlands are divided into only six fertility classes. The use of this classification requires the identification of only a few indicator plant species. The fertility classes, which have also been termed mire type groups, are: 1. fen-like, 2. herb-rich, 3. ordinary sedge, 4. small-sedge, 5. cottongrass and dwarf-shrub and 6. fuscum.

The following division into six classes has been used for the classification of peat quality:

1. LBC, BC, EuLC, EuSC	*Carex*-dominated peats
2. CL, LC	
3. C	
4. LSC, SC	
5. LCS, CS, ErCS, LS	*Sphagnum*-dominated peats
6. ErS, S	

Explanation of letter code: B = *Bryales*, C = *Carex*, Eu = *eutrophic*, Er = *Eriophorum*, L = *Ligno* (wood residue) and S = *Sphagnum*.

The samples were analysed for pH(H_2O) on a soil : water suspension (1: 2,5) and calcium, potassium and phosphorus extractable in acid ammonium acetate (VUORINEN and MÄKITIE 1955). In addition, organic carbon (wet digestion method) which was multiplied by 1,73 to give humus content and total nitrogen (Kjeldahl method) were determined on surface layer samples. The results are given in milligrams per litre of ground soil, dried at 35 °C (KURKI et al. 1965).

RESULTS

Most of the samples fell into mire type group 3 (ordinary sedge) and 5 (cottongrass and dwarf-shrub mires). By contrast, small-segde (4) and particularly fen-like mires (1) were rather poorly represented (Table 1). When a line was drawn through Jyväskylä to separate northern and southern Finland, most (81 %) of the better mire type groups 1.—3. occurred in northern Finland, conversely most (65 %) of the poorer types 4.—6. were found in southern Finland.

The nutrient status and some other chemical properties of the sampling sites are presented according to mire type group for the three layers in Table 1. The **pH value** of the peats was highest (approx. pH 5) for type group 1, falling fairly consistently to about pH 4 as the type group worstened, for all three layers. The difference between extreme mire type groups was about one pH unit for all layers, and there were scarcely any differences between different layers of the same type group. For most groups the standard deviation was nearly constant, about 0,3 pH units.

The determination of mire type according to content of **extractable calcium** can be seen in Table 1. The calcium content fell consistently from the most fertile to the least for all layers. The Ca content of mire type group 1 was about seven times that of group 6 for the surface and intermediate layers, six times for the lowest layer. The Ca content of the fen-like group (1149—1553 mg/l) was much, indeed surprisingly greater than that of the herb-rich group (637—827 mg/l). Otherwise the Ca content diminished evenly with worstening mire type group, and for the fuscum mires was only 156—242 mg/l.

The diminution of the relative low **potassium** contents of peats as the mire type group worstened was only slight. Particularly for surface samples, only the best (46 mg/l) and poorest (26

Table 1. Average chemical properties of six mire type groups in three layers.

Mire type	n	pH (H_2O)	S.D.	Ammonium acetate (pH 4,65) extractable nutrients mg/l soil: Calcium	S.D.	Potassium	S.D.	Phosphorus	S.D.	Org. C %	S.D.	Tot. N %	S.D.	C/N	S.D.
Layer 0—20 cm															
1. fen-like	23	5,06	0,53	1 149	803	46	31	4,1	3,9	40,2	3,7	1,77	0,48	24	6,4
2. herb-rich	136	4,76	0,34	637	461	39	32	2,5	2,2	41,1	4,4	1,94	0,51	23	8,3
3. ordinary sedge	239	4,63	0,35	475	359	34	24	2,8	2,6	40,8	4,7	1,90	0,55	24	8,5
4. small-sedge	64	4,26	0,33	316	208	36	27	3,7	2,6	40,5	4,1	1,23	0,57	41	19,5
5. cottongrass and dwarf-shrub	245	3,99	0,30	259	157	35	23	4,6	3,4	40,9	3,3	0,98	0,42	49	18,1
6. fuscum	144	4,00	0,27	157	109	26	22	3,2	2,7	40,4	3,3	0,70	0,36	67	21,7
	851														
Layer 20—40 cm															
1. fen-like	23	5,04	0,47	1 358	1 043	20	12	1,3	1,3						
2. herb-rich	136	4,80	0,33	750	578	16	14	0,9	1,0						
3. ordinary sedge	239	4,70	0,35	580	498	16	14	1,3	1,7						
4. small-sedge	64	4,28	0,33	434	326	21	18	2,1	1,9						
5. cottongrass and dwarf-shrub	245	4,01	0,34	322	251	19	14	3,1	2,8						
6. fuscum	144	3,91	0,29	189	148	17	15	2,9	2,6						
	851														
Layer 40—60 cm															
1. fen-like	23	5,01	0,46	1 553	1 124	18	10	1,1	1,2						
2. herb-rich	136	4,86	0,32	827	622	13	10	0,7	0,7						
3. ordinary sedge	239	4,77	0,34	634	520	13	12	0,8	1,0						
4. small-sedge	64	4,36	0,32	462	406	15	13	1,1	0,9						
5. cottongrass and dwarf-shrub	245	4,10	0,40	383	335	13	11	1,7	1,6						
6. fuscum	144	3,97	0,32	242	191	12	9	2,0	1,9						
	851														

mg/l) values differed significantly from one another. Within each mire type group, the K content of the surface layers was 2—3 times higher than for the intermediate and lowest layers.

The **phosphorus** content of peats varied irrespective of mire type group, and the variation of the material was large. Phosphorus contents were highest in the surface layers of the peats, where means for the different mire type groups varied from 2,5 to 4,6, and lowest for the bottom layer with values from 0,7 to 2,0. Contents for the intermediate layer fell between these ranges.

As well as calcium content and pH value, the **total nitrogen** content of the peat follows the classification of the mire type groups. The nitrogen percentage estimated on surface samples fell from a mean of 1,94 for mire type group 2 to 0,70 for the poorest group. The nitrogen percentage (1,77) for the fen-like group (1) was somewhat lower than for the herb-rich (2) or ordninary sedge (3) groups. It might depend on the fewness of that group.

The mean content of **organic carbon** for the various mire type groups was surprisingly constant, 40,2—41,1, and the variation of the material was low.

For the three most fertile mire type groups, the **carbon/nitrogen** (C/N) **ratios** indicating nitrogen availability were nearly the same

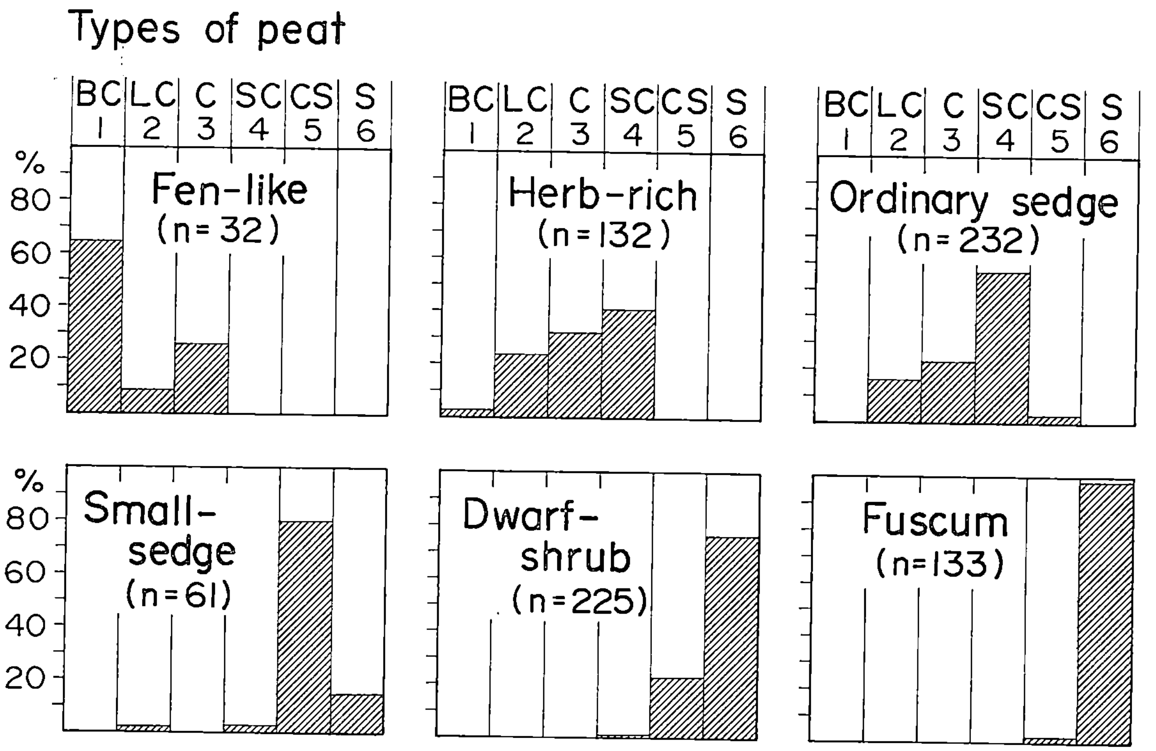

Fig. 1. Percentage distributions of peat types within mire type groups. Peat types: 1. BC, 2. LC, 3. C, 4. SC, 5. CS and 6. S (more detailed explanation of letter code on p. 86).

23—24, or considerably more favourable than means for the poorest mire type groups (41—67).

For the 0—20 cm layer, the distribution of different peat types within the various mire type groups are shown in Fig. 1. The most ertile group contained only peats belonging to the three best types, in which *Bryales*, *Carex* and *Ligno* residues predominate. By contrast, the poorest mire type group consisted almost entirely of a *Sphagnum* or *Eriophorum-Sphagnum* peat type. Within the herb-rich and ordinary sedge type groups the distribution of peat quality were very similar. Of the small-sedge group cases, 80 % fell into the *Sphagnum*-dominated peat category. Within a mire type group, distributions of peat quality based on the intermediate (20—40 cm) or lowest (40—60 cm) layer agreed fairly closely with those for the surface layers in Fig. 1.

DISCUSSION

The mire type classifications used in Finland are based on the system devised by A. K. Cajander (1913), who chose peatland vegetation as the criterion for his classification. On the basis of their chemical and physical properties, Kotilainen (1927) divided mire types into ten fertility classes, i.e. he determined the bonity for each mire type. The bonity of a peatland thus reflects its nutrient status. The fertility class of a peatland determined from the natural vegetation provides a good basis for all measures designed to raise the productivity of peatlands.

For each basic type of peatland, the natural vegetation displays features which indicate the abundance in the peat of available nutrients. In his investigations HUIKARI (1952) has found that a practical fieldsman needs to identify only a few indicator species to achieve fair accuracy in classifying peatlands according to utilization value (HUIKARI et al. 1963). This mire type group or fertility classification (6 classes) designed to determine suitability of peatlands for forest drainage, has also been used by the Institute of Soil Science. The bipartition of peats into *Carex*-dominated and *Sphagnum*-dominated, as used in soil mapping, fits in well with classification into mire type groups. Mire types referred to by different workers can readily be allotted to appropriate fertility classes, which enables comparisons of different studies.

According to KARESNIEMI (1975), the pH of fens and fen-like pine swamps (corresponding to mire type group 1) of the Kemihaara reservoir area was 5,3, while the pH of *Sphagnum fuscum* bogs (mire type group 6) in the same area was only 3,5. The increase in acidity from the most fertile to the poorer peatlands corresponds fully to, but is more pronounced than, the situation in the present study. Likewise HEIKURAINEN (1979), who using his own mire type classification interpolated the results of several previous investigators, obtained for peats from the three main mire types (treeless peatlands, spruce swamps, pine swamps), each with the additional qualification fen-like pH values from 5,5—5,8. At the herb-rich level the pH was 4,8—5,0, and for the poor fuscum pine swamp 3,4.

The calcium content, together with the wetness are the most important determinants of mire type (PUUSTJÄRVI 1968). The increase in calcium content concurrent with improvement in bonity has been confirmed analytically by KIVINEN (1933), KOTILAINEN (1927) and VALMARI (1956). This conclusion is also supported by the results of analyses on our soil mapping material, for which the surface layers of fen-like peatlands contained 1149 mg of extractable calcium per litre of air-dried soil, whilst the *Sphagnum* peatlands held only 157 mg/l. In this investigations on peatland forests, WESTMAN (1979) determined the total content of Ca on samples of different fertility levels. Although his values are not directly comparable with values for extractable calcium, WESTMAN still found that total values fell as the fertility level dropped.

No dependence between potassium content and the bonity of a peatland was found by either VALMARI (1956) or PUUSTJÄRVI (1968). Nevertheless, moisture conditions are reflected in potassium values. In his summary, HEIKURAINEN (1979) states that a dense stand of trees increases contents of both potassium and phosphorus in the peat. Similarly, in nutrient studies made on peats of the soil mapping material at the Institute of Soil Science (URVAS et al. 1979), it was noticed that both *Ligno Carex* and *Ligno Sphagnum* peat had higher potassium and phosphorus contents than did other *Carex* and *Sphagnum* peats. In spite of this, when the same material was classified according to mire type group, no clear differences in K and P contents were observed. WESTMAN (1979) points out that there are differences in the extractability of potassium between mires in different regions of the country, and since our material comprised samples from the south coast to Lapland, varying extractability may have increased the variation in our results.

In his studies on the bonity of northern Finnish peatlands, VALMARI (1956) established that differences in the phosphorus status of various types of natural peatlands fail to correlate with bonity. Variations in the phosphorus content of peats, and the dependence of phosphorus on pH have been examined by several workers (eg. PUUSTJÄRVI 1956, LAKANEN 1971), but no clear relationship between bonity and phosphorus content has been found. In the present investigation, too, mean phosphorus contents vary in a random manner over different mire type groups. The only consistent feature was a diminution in phosphorus content with increasing depth for all mire type groups. In connection with their studies on the vertical distribution of major nutrients in *Sphagnum* peats, PAKARINEN and TOLONEN (1977) arrived at a similar conclusion.

In natural mires, eutrophic *Sphagnum Carex* peats, *Bryales Carex* and *Carex* peats contain more nitrogen than *Sphagnum* peats (KIVINEN 1933). The former types of peat form in fen-like, herb-rich and ordinary sedge mires, whilst *Sphagnum* peat forms in mire type group 6 (fuscum). Most of the recent nutrient studies on peatlands have been made with reference only to the type of peat; there is seldom any mention of mire type or mire type group. In the peatland study of the Kemihaara reservoir area, fertility is determined according to mire types (KARESNIEMI 1975). The mean nitrogen content of fens (corresponding to mire type group 1) was 1,61, of treeless *Carex* peatlands 1,63 and of treeless *Sphagnum* peatlands 0,95. In the present study the N contents of the corresponding mire type groups were 1,77, 1,90 and 0,70. The trend is the same in both cases, although the Kemihaara values represent only a single mire complex.

The quality of the organic constituents of a peat are closely defined by the ratio of carbon to nitrogen (C/N). The ratio is highest for *Sphagnum* peats, and decreases as the proportion of *Sphagnum* residues diminishes in the peat. When the organic constituents have decomposed completely, the C/N ratio of a soil settles down to a value near 10 (KIVINEN 1933). In the present case, where an attempt has been made to judge the practicability of a mire type classification for determining the cultivation value of peatlands, it is clear that the C/N ratio of the surface layers of the three best type groups was, from an agricultural standpoint, rather favourable (23—24). Since the content of organic carbon in all mire type groups was nearly the same, the diminution in nitrogen content for the three poorest mire type groups can be clearly seen in the rise in C/N ratio from the small-sedge mires (41) to the *Sphagnum fuscum* mires (67).

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SELOSTUS

Ravinteisuus soiden eri tyyppitasoilla.

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Maatalouden tutkimuskeskus

Tutkimusaineisto on saatu maataloudellisen maaperäkartoituksen yhteydessä kootuista luonnontilaisten soiden turvenäytteistä. Maaperäkartoitusalueita oli 14, eteläisin Espoo ja pohjoisin Rovaniemi. Näytteenottokohtia oli 851 ja näytteitä yhteensä 2 553. Näytteenottokohdat ryhmiteltiin käytännön metsäojitusta varten laaditun hyvyysluokituksen (HUIKARI ym. 1963) mukaisesti kuuteen tyyppitasoon: 1. lettoinen, 2. ruohoinen, 3. suursarainen, 4. piensarainen, 5. tupasvillainen tai isovarpuinen ja 6. rahkainen. Tutkimuksen tarkoitus oli katsoa, kuinka luotettavasti vain muutamiin opaskasveihin perustuvalla luokituksella käytännön kartoittajat pystyvät suot luokittelemaan, ja millaisia ovat eri tyyppitasojen ravinneluvut.

Parempien tyyppitasojen (1, 2, 3) näytteenottokohdista oli 81 prosenttia Rovaniemen, Tornion ja Ruukin kartoitusalueilta, kun taas heikompien tasojen (4, 5, 6) tapauksista 65 prosenttia sijoittui Etelä-Suomen alueille. Parhaiden suotyyppien turpeet olivat saravaltaisia ja karumpien vastaavasti rahkavaltaisia kuvan 1 mukaisesti.

Turvenäytteiden keskimääräinen pH-arvo laski noin yhdellä pH-yksiköllä siirryttäessä lettotasolta rahkatasolle. Keskimääräisistä ravinnearvoista liukoisen kalsiumin ja kokonaistypen määrät osoittivat parhaiten tyyppitasojen erilaisuuden. Kalsiumpitoisuus nousi 157:stä 1149 milligrammaan litrassa turvetta ja typen pitoisuus 0,70:stä 1,94 prosenttiin tyyppitason parantuessa. Kun turpeiden kokonaishiilipitoisuus oli kaikilla tyyppitasoilla keskimäärin samaa luokkaa, pieneni myös C/N-suhdeluku tyyppitason parantuessa. Liukoisen kaliumin ja fosforin keskimääräisten pitoisuuksien poikkeamat eri tyyppitasojen kesken olivat vähäisiä eikä mitään säännönmukaisuutta ilmennyt.

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THE ESTIMATION OF SOIL LIME REQUIREMENT IN SOIL TESTING

VÄINÖ MÄNTYLAHTI and TOIVO YLÄRANTA

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The method of estimating lime requirement used in Finnish soil testing was compared with a titrimetric method in which the theoretical amount of liming material is determined to having the soil pH to a desired level.

According to this investigation, liming recommendations made for clay, coarse mineral and organogenic soil type groups which are based solely on $pH(H_2O)$ or $pH(CaCl_2)$ measurements give a more realistic assessment of lime requirement than do the results of a soil testing analysis, especially for the clays and coarse mineral soils.

From the coarse classification of soils into three groups, it follows that a given group can comprise very different soils. As a result, objectives for exchangeable calcium contents by the soil testing method may exceed the effective, cation exchange capacity.

The results of this study indicate that calcium analyses should be discontinued in evaluation of soil lime requirement based on the Finnish soil testing method.

Index words: Soil $pH(H_2O)$ and $pH(CaCl_2)$, lime requirement in soil.

INTRODUCTION

The acidity of a cultivated soil increases with the leaching of nutrients, with nutrient uptake by plants, intensive fertilization and with precipitation of sulphur from the air. On much of the Finnish land area, soils are too acid for the cultivation of demanding crop species or varieties. Excessive acidity reduces the availability of phosphate fertilizers and creates an unfavourable environment for micro-organisms.

Finnish soil acidity trends have improved slightly. Nevertheless, 85—95 % of the northern Finnish and Pohjanmaa land area, 80—90 % of central Finland, 75—85 % of southern Finland, 60—70 % of southwest Finland and 40—50 % of the land area in the Åland islands is in need of liming (KURKI 1978). The lime requirement has not diminished during the 1970's (KURKI 1979).

Soil acidity can be reduced by the application of basic materials such as ground limestone ($CaCO_3$). The difficulty lies in determining the amount of liming material needed to establish optimal growing conditions. The most rapid and economical determinations are provided by laboratory methods. The aim of the present study was to compare the efficiency of the method presently used in Finnish soil testing for determining lime requirement (KURKI 1977) with that of a titrimetric method in which the amount of liming material is calculated as that required to raise the soil pH to a given level.

MATERIAL AND METHODS

The material investigated comprised 196 samples taken from the plough layer (5—15 cm) of timothy leys from various parts of Finland. The samples fell into three groups as shown in Table 1.

pH(H_2O), pH($CaCl_2$), electrical conductivity, organic carbon and acid ammonium acetate (0,5 M CH_3COONH_4, 0,5 M CH_3COOH, pH 4,65) extractable calcium were determined for all soils. In addition, $Ca(OH)_2$ increments were used to determine a titration curve for each soil.

Values for pH(H_2O) and pH($CaCl_2$) were made on soil solution suspensions (25 ml of soil + 62,5 ml H_2O or 0,01 M $CaCl_2$ solution). The pH(H_2O) measurement was made after suspension overnight, whereas the pH($CaCl_2$) was measured 2 hours after the addition of the $CaCl_2$ solution. Prior to measuring pH(H_2O), conductivity was measured on the overlying solution before stirring.

Organic carbon was determined by a modification (TARES and SIPPOLA 1978) of ALTEN's wet digestion method.

Extractable calcium assessed by the method used in Finnish soil testing (VUORINEN and MÄKITIE 1955).

To obtain the titration curve, 62,5 ml of 0,01 M $CaCl_2$ solution which was 0,0055 M with respect to $Ca(OH)_2$ was added to one 25 ml sample of soil, and 62,5 ml of 0,01 M $CaCl_2$ solution which was 0,0103 M with respect to $Ca(OH)_2$ was added to another. In the case of the organogenic soils, 12 samples required an extra addition of 0,0103 M $Ca(OH)_2$ solution, bringing the soil : solution ratio to 1 : 5. According to RYTI (1965), pH($CaCl_2$) values are practically independent of soil : solution ratios within the range 1 : 2,5—1 : 10.

The $Ca(OH)_2$ solutions were prepared by adding 0,5 g or 1,0 g of crystalline $Ca(OH)_2$ to one litre of 0,01 M $CaCl_2$ solution. After careful shaking, the mixture was allowed to stand for about 20 hours, after which the solution was filtered and the molarity of the filtrate checked by titration with hydrochloric acid.

The samples were allowed to remain in contact with the solution, which was stirred daily, for periods of 4, 6 and 10 days, at the end of which the pH of the stirred suspension was measured. A standing period of 6 days prior to measurement proved sufficient as the subsequent change in pH was slight.

Table 1. Soil sample means and 95 % confidence limits for pH(H_2O), electrical conductivity (10^{-2} S/m), organic carbon content (%) and exchangeable calcium content according to soil testing analyses (mg/l of soil).

Soil type group	No. of samples	pH(H_2O)	pH($CaCl_2$)	Electrical conductivity	Organic carbon	Ca
Clay soils	69	5,63±0,05	4,79±0,05	0,70±0,04	3,5±0,3	1 650±110
Coarse mineral soils	65	5,56±0,08	4,77±0,08	0,82±0,08	4,2±0,5	910± 80
Organogenic soils	62	5,05±0,09	4,37±0,09	1,5 ±0,2	26 ±3	1 390±150

Air-dried soil (∅ ≤ 2 mm) was used for the analyses.

The relationship between $pH(H_2O)$ and $pH(CaCl_2)$

The liming recommendations made according to the Finnish soil testing method are aimed at raising the $pH(H_2O)$ of normally cultivated soils to about pH 6, and of peat soils to a value 0,5—1 pH unit lower (Kurki 1977). Since the titrimetric method involves measurement of $pH(CaCl_2)$, the relationship between $pH(H_2O)$ and $pH(CaCl_2)$ and also their difference in the material investigated were first determined. This step enabled estimation of the liming requirement by the titrimetric method. According to $pH(H_2O)$ and $pH(CaCl_2)$ measurements, the linear correlation coefficient in all soil type groups deviated from zero at the 99,9 % significance level (Table 2).

Multiple correlation coefficients in which electrical conductivity and organic carbon content were considered as additional variables gave scarely any improvement over linear values. The differences between pH values according to the different methods can be regarded as typical of Finnish cultivated soils (Table 2).

The values of $pH(H_2O)$ and $pH(CaCl_2)$ differ most for clay soils. This is in good agreement with the lower specific conductance of clay soils compared to that of coarse mineral or organogenic soils (Table 1). A doubling of the specific conductance (from the means of 0,70 and 0,82 for clay and coarse mineral soils, respectively, to 1,5 for organogenic soils) reduces the difference between pH values according to the two methods by 0,1 pH units (Tares 1979).

Table 2. Linear correlation coefficients and numerical differences between $pH(H_2O)$ and $pH(CaCl_2)$ with 95 % confidence limits.

Soil type group	Correlation coefficient between $pH(H_2O)$ and $pH(CaCl_2)$	Numerical difference between $pH(H_2O)$ and $pH(CaCl_2)$
Clay soils (69)	0,91***	$0,83 \pm 0,02$
Coarse mineral soils (65)	0,95***	$0,79 \pm 0,02$
Organogenic soils (62) ..	0,94***	$0,67 \pm 0,03$

The conversion of titration results to $CaCO_3$ requirements

In this study, two solutions of $Ca(OH)_2$ were used, corresponding to 0,69 me $Ca(OH)_2$ (62,5 ml 0,0055 M $Ca(OH)_2$) and 1,29 me $Ca(OH)_2$ (62,5 ml 0,0103 M $Ca(OH)_2$) per 25 ml of soil. The number of equivalents was used to determine the corresponding quantity of $CaCO_3$. This in turn was converted to weight of ground limestone on the assumption that the neutralizing agent in ground limestone contains 35 % Ca (Wikström 1978).

The liming requirement was obtained graphically from the curve describing pH as a function of $Ca(OH)_2$ additions. By calculating quantities of ground limestone per hectare (soil depth 20 cm) on the basis of calcium hydroxide additions and joining the points with a curve, the amounts of ground limestone could be read off at $pH(CaCl_2)$ 5,2 (corresponding to $pH(H_2O)$ 6,0, Table 2) for clay and coarse mineral soils. For organogenic soils, the corresponding amount was read off at $pH(CaCl_2)$ 4,8 (corresponding to $pH(H_2O)$ 5,5, Table 2).

Liming requirement based on Finnish soil testing method

In the method used in Finnish soil testing, class estimates of the acidity and calcium status are averaged for the soil within a given group (clay soils, coarse mineral soils and organogenic soils) to provide an estimate of the lime requirement. For example, if the acidity status is rather poor (class 2) but the calcium status satisfactory (class 4), the lime requirement falls into the fair (3) class (Tables 3 and 4, Kurki 1977).

Table 3. A classification of clay, coarse mineral and organogenic soils in a fertility study according to acidity and exchangeable calcium (KURKI 1977).

Fertility rating	Clay soils		Coarse mineral soils		Organogenic soils	
	$pH(H_2O)$	Ca mg/l	$pH(H_2O)$	Ca mg/l	$pH(H_2O)$	Ca mg/l
Good (5)	6,2—6,6	2 600—3 600	6,2—6,6	2 000—2 600	5,6—6,0	2 600—3 600
Satisfactory (4)	5,8—6,2	2 000—2 600	5,8—6,2	1 400—2 000	5,2—5,6	1 600—2 600
Fair (3)	5,4—5,8	1 500—2 000	5,4—5,8	800—1 400	4,8—5,2	1 000—1 600
Rather poor (2)	5,0—5,4	1 000—1 500	5,0—5,4	400— 800	4,4—4,8	600—1 000
Poor (1)	<5,0	<1 000	<5,0	< 400	<4,4	< 600

On the basis of Tables 3 and 4, separate curves were drawn of soil pH as a function of ground limestone additions (t/ha) for both organogenic and for coarse mineral soils and clay soils combined. Likewise, for each soil type group, soil pH was plotted as a function of exchangeable calcium. These curves were used to determine the precise lime requirement according to the soil testing method.

Table 4. Recommended liming rates for ley cultivation at different fertility levels on the basis of fertility studies (KURKI 1977).

Fertility rating	Ground limestone (t/ha)
Good (5)	—
Satisfactory (4)	2— 4
Fair (3)	4— 6
Rather poor (2)	6— 8
Poor (1)	8—12

RESULTS

A comparison of liming requirement estimates according to the soil testing method, $pH(H_2O)$ and $pH(CaCl_2)$ measurement with titrimetric estimate

The linear correlation was determined within each soil type group between the lime requirement assessment according to the soil testing method and the titrimetric estimate. The $pH(H_2O)$ assessment was obtained from the table used in Finnish soil testing solely on the basis of $pH(H_2O)$ values (KURKI 1977). The corresponding $pH(CaCl_2)$ assessment was read off the same table with the additional provision that the difference between $pH(H_2O)$ and $pH(CaCl_2)$ was 0,83 units for the clay soil group, 0,79 for the coarse mineral soils and 0,67 for the organogenic soils. In every case, the correlation coefficients deviated significantly from zero at the 99,9 % level (Table 5).

Table 5. Liming requirement estimates according to the soil testing method, $pH(H_2O)$ and $pH(CaCl_2)$ measurement with the titrimetric estimate.

Soil type group	Correlation coefficients of liming requirement estimates with titrimetric estimate		
	Soil testing estimate	$pH(H_2O)$ assessment	$pH(CaCl_2)$ assessment
Clay soils (69)	0,61***	0,87***	0,95***
Coarse mineral soils (65)	0,77***	0,89***	0,92***
Organogenic soils (62)	0,53***	0,72***	0,82***

When the result of the calcium analysis was excluded from the lime requirement estimate using the soil testing method ($pH(H_2O)$ and $pH(CaCl_2)$ assessment), values of the correlation coefficients increased within each soil type group (Table 5). The significance of differences between the correlation coefficients was tested with the »z transformation test» (SNEDECOR and COCHRAN 1972, p. 185). Correlation coeffi-

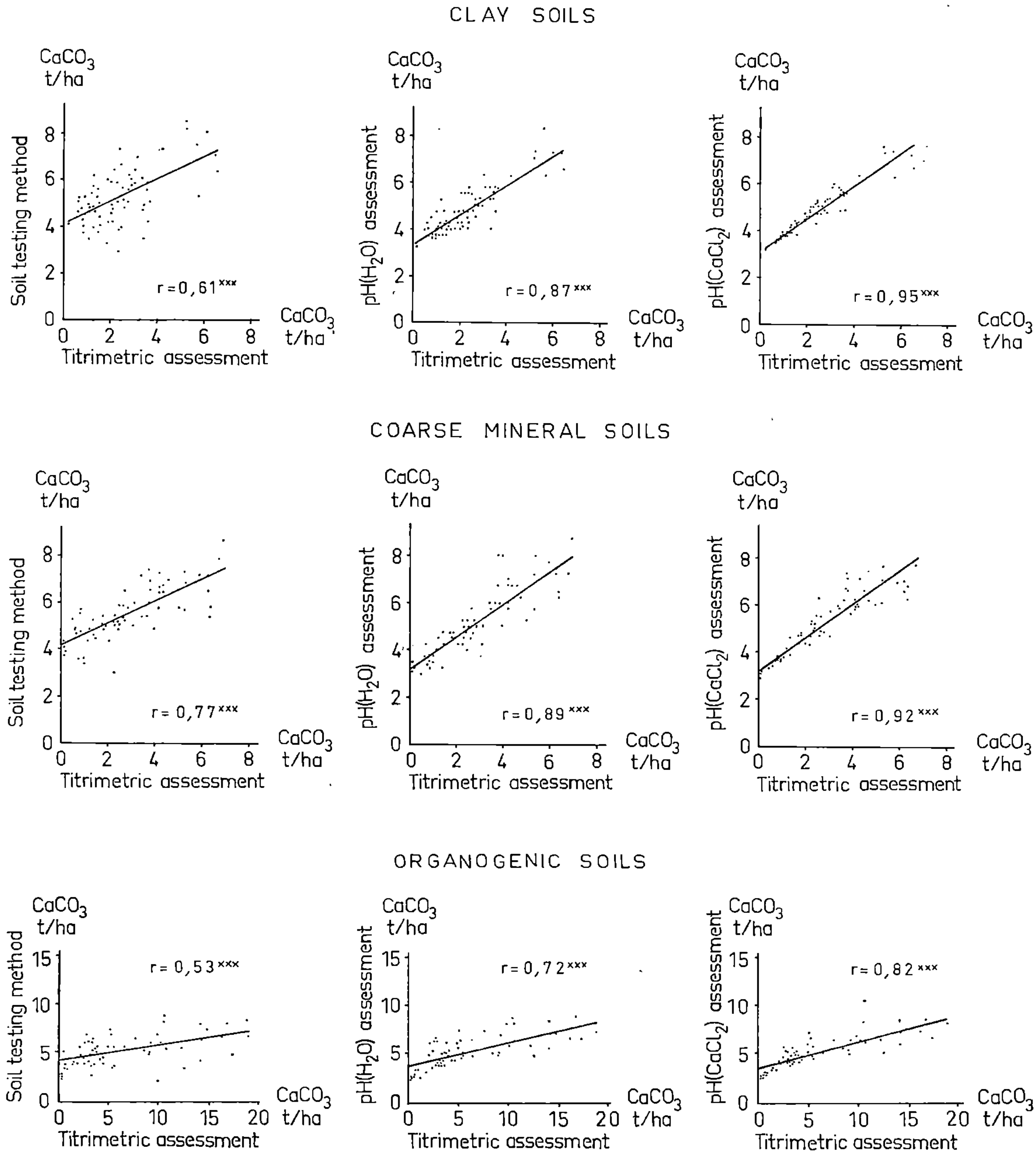

Fig. 1. The dependence of liming recommendations according to soil testing method, $pH(H_2O)$ assessment and $pH(CaCl_2)$ assessment upon the titrimetric assessment for different soil type groups.

cient values based on $pH(H_2O)$ assessment differed significantly from values based on the soil testing method, in the clay soils at a probability level of >99,9 %, in the coarse mineral soils at 97 %, and in the organogenic soils at a level of 91 %. Correspondingly, correlation coefficient values according to $pH(CaCl_2)$ assessment were significantly different from the soil testing method values with a probability of >99,9 % for the clays, 99,8 % for the coarse mineral soils and 99,7 % for the organogenic soils. In the clay soil group, correlation coefficients based on pH(H_2O) and pH($CaCl_2$) assessments differed from each other with 95 % probability.

For all soil type groups, a liming recommendation based solely on a measurement of pH(H_2O) appears to give a more realistic estimate than does the soil testing method when lime requirement based on the titrimetric method is used as a standard of comparison.

When the titrimetric method is used to account for recommendations based on the soil testing method, or on pH(H_2O) and pH($CaCl_2$) assessments (Fig. 1), the linear regressions are obtained as in the tabulation after the following paragraph.

It can be seen from the regression equations that the soil testing method recommends about 4 t/ha of ground limestone, whereas according to the titrimetric assessment liming is unnecessary. The soil testing is also characterised by only a slow increase in requirement of liming material with increasing estimates by the titrimetric method. This becomes especially apparent in the liming recommendations for organogenic soils. Mäkitie (1965) has also pointed out that recommendations based on the soil testing method give rise to a poor lime status in organogenic soils.

Soil type group	Soil testing estimate	pH(H_2O) assessment	pH($CaCl_2$) assessment
Clay soils (69)	$y = 4{,}02+0{,}49x$	$y = 3{,}37+0{,}61x$	$y = 3{,}26+0{,}67x$
Coarse mineral soils (65)	$y = 4{,}17+0{,}47x$	$y = 3{,}27+0{,}68x$	$y = 3{,}22+0{,}70x$
Organogenic soils (62)	$y = 4{,}15+0{,}16x$	$y = 3{,}72+0{,}24x$	$y = 3{,}52+0{,}27x$

Estimation of lime requirement according to pH(H_2O) and pH($CaCl_2$) measurements

A consideration of the analytical results reveals that liming recommendations based on the soil testing method differ from those based on the titrimetric method. On the other hand, it was found that assessments based on pH(H_2O) and pH($CaCl_2$) measurements described lime requirement by the titrimetric method better than did the soil testing estimates. In consequense, the titrimetric assessment of lime requirement was calculated as a function of pH measurement:

Soil type group	pH(H_2O) measurement	pH($CaCl_2$) measurement
Clay soils (69)	$y = 48{,}22-8{,}14x$	$y = 35{,}16-6{,}83x$
Coarse mineral soils (65)	$y = 34{,}78-5{,}74x$	$y = 31{,}49-6{,}01x$
Organogenic soils (62)	$y = 60{,}52-10{,}97x$	$y = 58{,}09-12{,}13x$

The values of correlation coefficients for these equations are numerically the same as in Table 5, but negative. The results are based on material in which pH measurements varied as follows:

Soil type group	pH(H_2O)	pH($CaCl_2$)
Clay soils (69)	4,9—6,0	4,2—5,1
Coarse mineral soils (65)	5,0—6,0	3,9—5,4
Organogenic soils (62)	4,2—5,6	3,3—4,8

The significance of so-called exchangeable calcium in accounting for the lime requirement was also examined by including exchangeable calcium as a determinant variable in addition to pH(H_2O) measurement in estimation of lime requirement by titrimetric assessment. In the clay soil group, this measure increased the coefficient of determination by 1,4 %, in the coarse mineral soils by 0,3 % and in the organogenic soils by 1,8 %.

For mineral soils, the optimal ratio of hydrogen to metallic cations for nutrient uptake by plants is held to be 1 : 3 ; the degree of base saturation must therefore be about 75 % of the cation exchange capacity (JONSSON 1978).

According to soil testing recommendations, the class satisfactory (4), e.g. for coarse mineral soils, corresponds exchangeable calcium to 1 400 mg/l of soil and pH(H_2O) 5,8. For the soil to hold so much exchangeable calcium at this pH, the cation exchange capacity would have to be more than 10 me/100 g of soil, or over 10 me/100 ml of soil, since according to SIPPOLA and TARES (1978) the average volume weight of Finnish mineral soils is almost unity. In addition, it should be borne in mind that according to VUORINEN and MÄKITIE (1955) the soil testing method displaces an average of 80 % of the exchangeable calcium from most cultivated soils. In surface samples (0—20 cm) of silt and loam soils (pH($CaCl_2$) 5,0), fine and coarse sandy soils including some moraine samples (pH($CaCl_2$) 4,9), KAILA (1971) gives mean values for the effective cation exchange capacity of about 9 me/100 g of soil. It follows from the wide differences in the cation exchange capacity that different soils at a given pH will display a correspondingly wide range of exchangeable calcium values. If estimates of exchangeable calcium contents are to be of any use in soil testing, they should be better related to cation exchange capacity.

It appears that requirements based on the Finnish soil testing method should be regarded with some scepticism. Inclusion of the calcium status worsens the liming assessment in all soil type groups examined, particularly in the clay soils. Acid ammonium acetate extractable calcium can only be used as an index of liming requirement as long as the factors affecting cation exchange capacity and degree of base saturation are the same. This is generally not the case. The results of our study indicate that a measurement of pH(H_2O) or pH($CaCl_2$) without any consideration of calcium status defines lime requirement more adequately.

On its own, however, a pH measurement gives only a qualitative index of lime requirement. In a soil with low pH and small cation exchange capacity, less lime is needed to raise the pH to a given level than is needed for a soil of similar pH but with a large cation exchange capacity. In such a case, the amount of liming material needed should be determined by more precise means than from measurements of pH(H_2O) or pH($CaCl_2$), e.g. by means of the titrimetric method described in this study. In practice, this involves only one $Ca(OH)_2$ addition (e.g. 0,005 M for mineral soils and 0,01 M for organogenic soils) when the soil: solution ratio is 1 : 5.

On the basis of our investigation, the calcium analysis can be omitted from routine soil testing analyses of liming requirement. A liming recommendation based solely on pH(H_2O) or pH($CaCl_2$) measurement better describes the titrimetric liming assessment than does a recommendation based on the Finnish soil testing method.

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SELOSTUS

Maan kalkitustarpeen määrittämisestä viljavuustutkimuksessa

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Maatalouden tutkimuskeskus

Viljelysmaiden happamuus lisääntyy ravinteiden huuhtoutumisen, kasvien ravinteiden oton, tehokkaan väkilannoituksen ja myös ilmasta laskeumana tulevan rikin seurauksena. Valtaosa pelloistamme onkin vaateliaiden kasvilajien ja -lajikkeiden viljelyn kannalta liian happamia.

Maan happamuutta voidaan vähentää lisäämällä emäksisesti vaikuttavia aineita, kuten kalkkikivijauhetta ($CaCO_3$). Vaikeutena on arvioida optimaalisten viljelyedellytysten luomiseksi tarvittava kalkitusainemäärä. Tämän tutkimuksen tarkoituksena oli verrata viljavuustutkimuksen kalkitustarpeen määritysmenetelmää ns. titrausmenetelmään, jonka avulla voidaan määrittää teoreettinen kalkitusainemäärä maan pH-arvon kohottamiseksi halutulle tasolle.

Kun kalkitussuositus tehdään maalajiryhmissä savimaat, karkeat kivennäismaat ja eloperäiset maat pelkän pH(H_2O)- tai pH($CaCl_2$)-mittauksen perusteella, saadaan tämän tutkimuksen perusteella etenkin savimaissa ja karkeissa kivennäismaissa viljavuustutkimusmenetelmän tuloksia todellisempi kuva kalkitustarpeesta.

Karkeasta kolmen ryhmän maalajiluokituksesta seuraa, että samaan ryhmään voi kuulua hyvin erilaisia maita. Näin ollen saattavat viljavuusanalyysissä vaihtuvan kalsiumin tavoitepitoisuudet ylittää efektiivisen kationinvaihtokapasiteetin.

Tämän tutkimuksen perusteella maan kalkitustarvetta arvioitaessa voitaisiin kalsiumanalyysi jättää pois rutiininomaisesta viljavuustutkimuksesta. Pelkän pH(H_2O)- tai pH($CaCl_2$)-mittauksen mukainen kalkitussuositus kuvaa titraustulkinnan mukaista kalkitustarvetta paremmin kuin viljavuustutkimukseen perustuva suositus.

ANNALES AGRICULTURAE FENNIAE, VOL. 19: 100—107 (1980)

Seria AGROGEOLOGIA ET -CHIMICA N. 102 — Sarja MAA JA LANNOITUS n:o 102

THE DEPENDENCE OF YIELD INCREASES OBTAINED WITH PHOSPHORUS AND POTASSIUM FERTILIZATION ON SOIL TEST VALUES AND SOIL pH

JOUKO SIPPOLA

SIPPOLA, J. 1980. **The dependence of yield increases obtained with phosphorus and potassium fertilization on soil test values and soil pH.** Ann. Agric. Fenn. 19: 100—107. (Agric. Res. Centre, Inst. Soil Sci., SF—01300 Vantaa 30, Finland.)

The study involves the fitting of results from phosphorus and potassium fertilizing experiments to response functions of the types $y = a + bx + cx^2$ and $y = a + b\sqrt{x} + cx$. The dependence of the coefficients of these response functions on respective soil test values and soil pH was studied.

No statistically significant difference was found between the two models in the fit into the experimental data. The best response to fertilizer phosphorus and to potassium was obtained on organic soils and the poorest on clay soils.

Soil pH was found to be an important factor in conjunction with the soil phosphorus test value in explaining the variance of the coefficients in response functions. The percentage of explained variance ranged from 4 to 18 % in the case of the quadratic model and from 1 to 9 % in the case of the square root model. The respective percentages for the potassium experiments were 1 to 28 % and 1 to 20 %, when the potassium test value was the only explanatory variable.

The inclusion of the soil test value in the response function simplifies the calculation of optimum fertilizer rates in economically variable situations. The difficulty, however, is that the response function itself is obtained as an average of several experiments.

Index words: Soil testing, yield response functions, phosphorus, potassium.

INTRODUCTION

The primary purpose of soil testing is to determine the fertility of soils for plant growing. It should also be the basis for fertilizer recommendations. The optimal use of fertilizers also involves the consideration of economical factors such as prices of fertilizers and crops. In this connection the value of soil testing is increased when we know that uncontrolled use of fertilizers may be extremely uneconomical, because the best response to fertilizers is obtained on soils with low fertility. Excessive use of fertilizers on soils with good fertility leads not only to economical losses by the farmer but it may also cause environmental risks.

The calibration of the results of soil tests with plant response to fertilizers involves the use of production functions (COLDWELL 1978). Although production functions have already been used for a long time, they have grown in importance in recent years. This is because the studies on the economics of fertilization have intensified and production functions are required when optimum use of fertilizers is determined for various situations.

Different types of mathematical functions have been used as production function models (IHAMUOTILA 1970, JONSSON 1974). Different types have been found to be superior depending on the study. Some of the functions are restricted in their use by the tediousness of the calculations required to estimate parameters (JONSSON 1974).

There is no generally approved type of production function. Therefore, the best fit to experimental data has usually been taken as the basis for choice of the model. The popularity of simple polynomial models such as quadratic and quadratic square root functions has increased. They are easily fitted to data by standard statistical procedures and other mathematical models have not proved to be significantly better. Therefore, in the present study quadratic and quadratic square root models were fitted to yield data obtained in local fertility trials on small grains (i.e. wheat, barley and oats) and hay. The dependence of the coefficients of these functions on soil test value, and in the case of phosphorus its dependence on soil pH, were investigated in order to find a reliable basis for interpretation of soil test results.

MATERIAL AND METHODS

The results obtained in local phosphorus and potassium fertilization trials were used in the study (SIPPOLA and MARJANEN 1978). The experimental fields were located throughout Finland, but the experiments involving small grains were concentrated in the southern part of the country. All three main Finnish soil type groups, clay soils, coarse mineral soils and organic soils, were included. The study material consisted of 375 trials on phosphorus and 235 trials on potassium.

Basic nitrogen fertilization was 52 kg/ha. In phosphorus trials the basic potassium fertilization rate was 100 kg/ha, and in potassium experiments the phosphorus rate was 35 kg/ha. The treatment factors in the phosphorus experiments were 0, 17, 35, 52 and 70 kg/ha in the form of superphosphate. The treatments in the potassium experiments were 0, 42, 84, 126 and 168 or 0, 50, 100, 150 and 200 kg/ha in the form of muriate of potash. The experiments involved four replications. Spring wheat, barley and oats were the test crops in the experiments involving small grains, but the results are treated as one group (in kg/ha). The hay crop in the experiments was timothy.

The soils of the experimental fields were tested for easily extractable phosphorus and potassium using the method of VUORINEN and MÄKITIE (1955). Soil pH was measured from a soil-water suspension (1 : 2,5 by volume).

The quadratic, $y = a + bx + cx^2$, and quadratic square root, $y = a + b\sqrt{x} + cx$, polynomial functions were fitted to the yield increase results of each field using a Compucorp 455 desk calculator. The dependence of the obtained coefficients on soil test values and soil pH was studied using standard regression analysis methods (SNEDECOR and COCHRAN 1972).

Response functions for phosphorus and potassium

The fit of the models, $y = a + bx + cx^2$ and $y = a + b\sqrt{x} + cx$, to experimental data was in most cases good. The results of a few experiments were discarded due to nonsignificant correlation. Despite the statistically nonsignificant differences between models, the calculated correlation coefficients were more often higher in numerical value in the case of the quadratic square root model for both phosphorus and potassium experiments than in the case of the quadratic model.

The apparent non-fit to each other of some of the models in Figs. 1 and 2, which are drawn according to the mean values of coefficients, was due to large variation in the coefficients of individual experiments.

According to the mean values of the coefficients in fitted functions, the best response of cereals to phosphorus fertilizers was obtained on organic soils (Table 1), and was about twice as high as on clay soils. The same order of phosphorus effect between soil types has also been reported earlier in Finland and responses similar to those indicated by linear terms in the quadratic model have been obtained on newly reclaimed areas (Tennberg 1955).

The mean value of the quadratic term was highest in the case of organic soils, and therefore, according to the model, the yield drops very quickly at higher phosphorus doses (Table 1, Fig. 1). Although in the square root model the linear term for organic soils is negative, the value of the function increases up to the highest phosphorus rates used in the experiments. This indicates a principal difference between the two types of model in this particular set of experiments.

According to the means of the regression coefficients, organic soils also responded best to potassium, as was known previously (Marjanen and Valmari 1975). Clay soils responded least because of the large potassium reserves found in these soils (Fig. 2).

All the quadratic functions describing the response of small grains and hay to potassium fertilization have a clear maximum in the range of applied fertilizer rates. On the other hand, the square root functions have such a maximum only in the case of clay soils.

The fit of functions to experimental data measured by the magnitude of correlation coefficients did not indicate the superiority of either of the models. Jonsson (1974) also

Table 1. The mean values of the coefficients b and c in quadratic ($y = a + bx + cx^2$) and quadratic square root ($y = a + b\sqrt{x} + cx$) functions fitted to the yield increases obtained in phosphorus fertilization trials.

	n	quadratic		quadratic square root	
		b	c	b	c
Small grains					
Clay soils	79	10,4	—0,0775	40,6	1,27
Coarse mineral soils	88	14,0	—0,1183	53,7	1,05
Organic soils	56	22,2	—0,2899	79,2	—1,38
Hay					
Clay soils	20	12,8	—0,0662	43,9	3,54
Coarse mineral soils	57	21,0	—0,1658	69,0	3,22
Organic soils	75	35,0	—0,3325	147,8	—2,38

Table 2. The mean values of the coefficients b and c in quadratic ($y = a + bx + cx^2$) and quadratic square root ($y = a + b\sqrt{x} + cx$) functions fitted to the yield increases obtained in potassium fertilization trials.

	n	quadratic		quadratic square root	
		b	c	b	c
Small grains					
Clay soils	28	3,09	—0,0200	32,9	—2,47
Coarse mineral soils	29	4,05	—0,0137	31,0	—0,47
Organic soils	20	8,33	—0,0387	56,5	—1,45
Hay					
Clay soils	23	7,53	—0,0331	53,5	—1,50
Coarse mineral soils	38	12,8	—0,0488	94,2	—1,66
Organic soils	97	16,7	—0,0571	113,8	—0,42

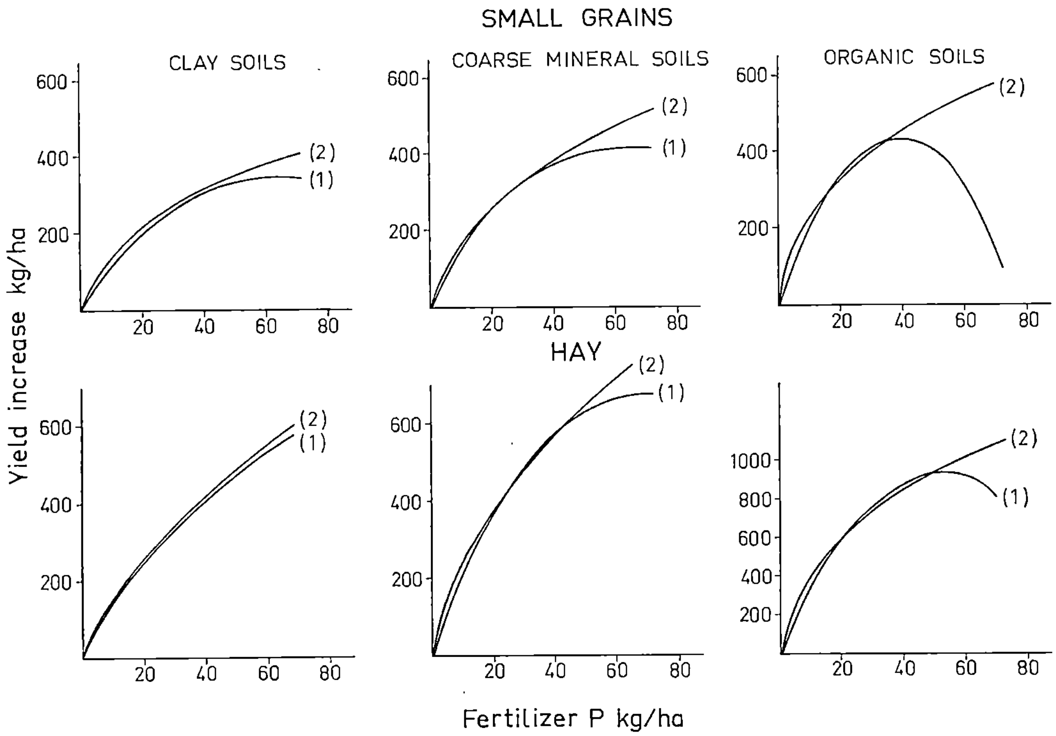

Fig. 1. Comparison of the phosphorus response functions $y = a + bx + cx^2$ (1) and $y = a + b\sqrt{x} + cx$ (2).

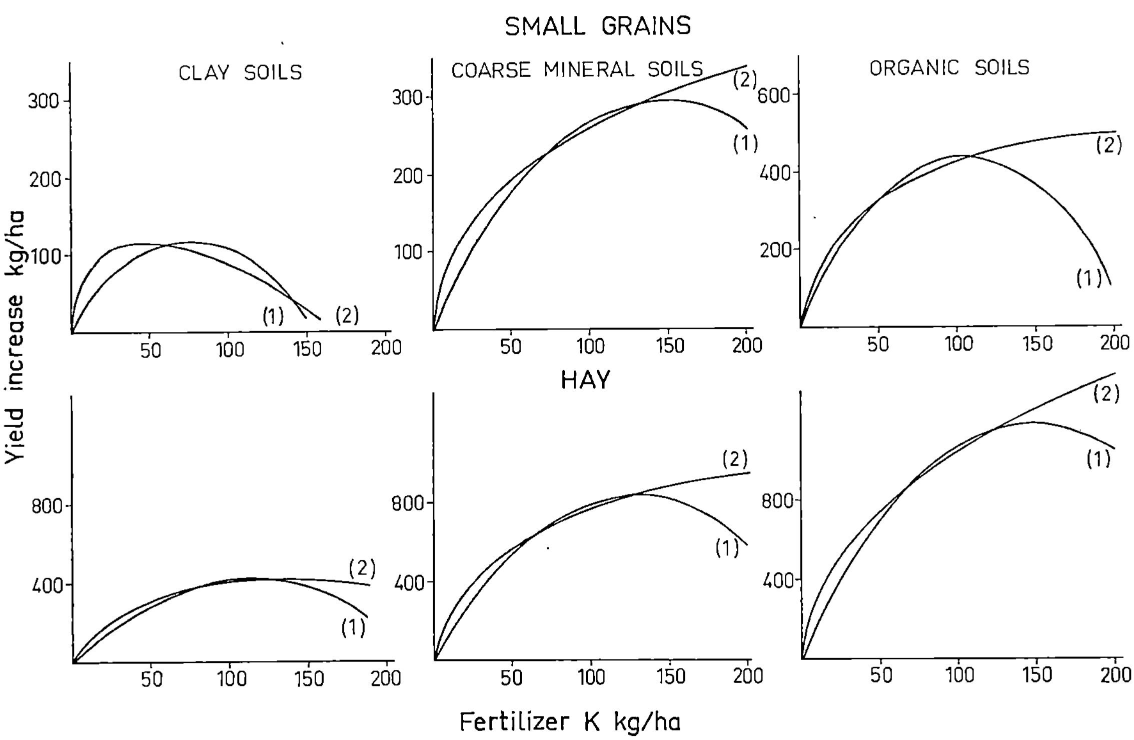

Fig. 2. Comparison of the potassium response functions $y = a + bx + cx^2$ (1) and $y = a + b\sqrt{x} + cx$ (2).

Table 3. The dependence of the coefficients b and c in the yield increase response function $y = a + bx + cx^2$ on the soil pH and soil P-test value.

	n	b	R	c	R
Small grains					
Clay soils	79	97,0—15,5 pH —0,15 P value	0,43***	—1,15+0,19 pH +0,002 P value	0,37***
Coarse mineral soils	88	106,1—16,8 pH —0,06 P value	0,35***	—0,93+0,15 pH +0,001 P value	0,22*
Organic soils	56	45,4— 3,1 pH —1,95 P value	0,34*	—0,51+0,02 pH +0,027 P value	0,24
Hay					
Clay soils	20	—41,5+ 9,4 pH +0,30 P value	0,20	1,58—0,28 pH —0,011 P value	0,35
Coarse mineral soils	57	106,1—14,1 pH —1,33 P value	0,29*	—1,79+0,30 pH —0,006 P value	0,30*
Organic soils	75	—37,7+15,9 pH —1,03 P value	0,29*	0,28—0,14 pH —0,012 P value	0,23*

arrived at such a conclusion in his study of the quadratic and square root production functions fitted to results of nitrogen fertilizing experiments. Colwell (1967) found indications of the superiority of the square root model and later Colwell (1978) used only the square root model in fertilizer requirement studies. Because in the present study no clear decision could be made concerning the superiority of either of the models, both were used in the study of the dependence of the coefficients of response functions of individual experiments on respective soil test values.

The dependence of coefficients of fertilizer response functions on soil test value and pH

When the dependence of coefficients of phosphorus response functions on soil test values and pH was studied, it was found that soil pH correlated better than P-test value. Therefore, in the case of phosphorus experiments, pH was also included as an independent variable in functions for estimating the regression coefficients (Table 3).

According to these functions, pH had a marked effect, especially on clay and coarse mineral soils. The increase in soil pH diminishes the linear coefficient, which indicates lower response to phosphorus fertilizers. Exceptions to this were the experiments concerning hay on clay and organic soils. Other phosphorus fertilization experiments have also shown that the best response to phosphorus is obtained on soils with low pH (Keränen and Marjanen 1972). The reduction in fertilizer response due to increase in soil P-test value is logical. The second degree term mainly diminishes due to an increase in both soil pH and soil P-test

Table 4. The dependence of the coefficients b and c in the yield increase response function $y = a + b\sqrt{x} + cx$ on the soil pH and soil P-test value.

	n	b	R	c	R
Small grains					
Clay soils	79	422— 68,8 pH —0,69 P value	0,27*	—32+ 6,2 pH —0,079 P value	0,18
Coarse mineral soils	88	587— 98,7 pH +1,26 P value	0,30**	—31+ 6,1 pH —0,236 P value	0,16
Organic soils	56	27+ 16,0 pH —7,16 P value	0,24	21— 4,7 pH +0,206 P value	0,13
Hay					
Clay soils	20	—417+ 77,7 pH +5,67 P value	0,28	97—15,9 pH —1,02 P value	0,42
Coarse mineral soils	57	700—113,4 pH —0,70 P value	0,28	—84+17,2 pH —1,61 P value	0,31*
Organic soils	75	—123+ 63,6 pH —6,60 P value	0,28	— 6+ 0,1 pH +0,46 P value	0,15

Table 5. The dependence of the coefficient b and c in the yield increase response function $y = a + bx + cx^2$ on the soil K-test value.

	n	b	r	c	r
Small grains					
Clay soils	28	2,6+0,003 K value	0,07	—0,0082—0,0001 K value	—0,22
Coarse mineral soils	29	8,8—0,046 K value	—0,52**	—0,0355+0,0002 K value	0,38*
Organic soils	20	13,1—0,084 K value	—0,29	—0,0649+0,0005 K value	0,25
Hay					
Clay soils	23	20,4—0,082 K value	—0,53**	—0,0917+0,00037 K value	0,41*
Coarse mineral soils	38	20,3—0,077 K value	—0,38*	—0,0873+0,00039 K value	0,33*
Organic soils	97	26,2—0,142 K value	—0,38**	—0,0968+0,00059 K value	0,27**

value. The dependence of regressions on soil pH and soil test values was in most cases statistically significant and 4—18 % of the variation of the coefficients in quadratic equations was explained by these factors.

The dependence of the coefficients in the square root model on these soil factors was generally smaller (Table 4). The percentage of explained variation ranged from 1 to 9 %.

In potassium experiments the soil pH was not significant in combination with the K-test value in explaining the variation of coefficients in potassium response functions, and therefore only the regression on soil test values was calculated (Tables 5 and 6). The regression of the coefficients in the quadratic model were statistically significant except in the small grain experiments on clay and organic soils. The variation of coefficients explained by regression was 1—28 % and was mostly more than that in the phosphorus experiments. The decrease in the linear coefficient when soil K-test value increased is logical. In accordance with the phosphorus experiments the second degree term diminished when the soil test value increased. The dependence of the coefficients of the square root model on soil K-test value did not reach the significance level as often as in the quadratic model.

When response functions are used to calculate optimum fertilizer rates the selection of the model is important. As can be seen in Figs. 1 and 2, in some cases the two models closely approach each other, but in other cases the optimum rates deviate greatly. According to the present results, the quadratic model results in higher optimum rates when the cost of fertilizers is high, but when the fertilizers are relatively cheap the square root model results in higher optimum rates. This is because of the

Table 6. The depencence of the coefficients b and c in the yield increase response function $y = a + b\sqrt{x} + cx$ on the soil K-test value.

	n	b	r	c	r
Small grains					
Clay soils	28	5,2+0,16 K value	0,28	1,1—0,020 K valuc	—0,37
Coarse mineral soils	29	73,0—0,407 K value	—0,45*	—2,4+0,018 K value	0,25
Organic soils	20	91,0—0,607 K value	—0,22	—3,0+0,028 K value	0,14
Hay					
Clay soils	23	140 —0,56 K value	—0,32	—3,5+0,012 K value	0,09
Coarse mineral soils	38	190 —0,93 K value	—0,45**	—7,6+0,068 K value	0,41*
Organic soils	97	174 —0,89 K value	—0,24*	—1,4+0,015 K value	0,05

maximum in quadratic models in the range of applied fertilizer rates. The difficulty in choosing the model may be simplified by the knowledge that there are also many other uncertainties when optimum fertilizer rates are determined for a future crop and a good selection between all the factors has to be made. Of these factors, those connected with weather are impossible to control. The selection of plant varieties, methods of cultivation and fertilizer application also affect fertilizer efficiency. Soil testing, as shown by this study, gives useful information concerning an influencing factor which can be corrected to a level that does not limit growth.

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SELOSTUS

Fosfori- ja kaliumlannoituksella saatujen sadonlisäysten riippuvuus maan viljavuusluvusta ja pH:sta

Jouko Sippola

Maatalouden tutkimuskeskus

Tutkimuksessa käsitellään paikallisissa nousevien fosfori- ja kaliummäärien kokeissa saatuja sadonlisäyksiä käyttäen hyväksi tuotantofunktioita $y = a + bx + cx^2$ ja $y = a + b\sqrt{x} + cx$.

Mallien sopivuudessa tulosaineistoon ei todettu merkitseviä eroja. Neliöjuurifunktion selvitysaste oli useammin suurempi kuin toisen asteen yhtälön selvitysaste. Parhaat sadonlisäykset saatiin sekä fosforilla että kaliumilla eloperäisillä mailla (Kuvat 1 ja 2). Savimailla lannoitteiden vaikutus oli vähäisin.

Tuotantofunktioiden kertoimien riippuvuutta maan viljavuusluvusta pyrittiin selvittämään regressioanalyysin avulla. Fosforilannoituskokeissa maan pH osoittautui maan fosforiluvun ohella tärkeäksi fosforilannoituksen tehoon vaikuttavaksi tekijäksi. Nämä tekijät yhdessä selittivät 4—18 % toisen asteen funktion kertoimien vaihtelusta. Neliöjuurimallin kertoimien vaihtelun selvitysaste oli 1—9 %.

Maan kaliumluku selvitti 1—28 % kaliumlannoituskokeiden tuloksista laskettujen toisen asteen yhtälöiden kertoimista. Neliöjuuriyhtälön kertoimien vaihtelusta kaliumluku selvitti 1—20 %.

Käytettäessä tuotantofunktiota optimilannoitemäärien laskemiseen päädytään eri tuloksiin mallin valinnasta riippuen. Lisäksi optimilannoitemäärän arvioiminen tietämättä tulevan kasvukauden olosuhteita on vaikeaa. Tämän tutkimuksen perusteella viljavuusanalyysiin perustuvat lannoitussuositukset antavat kuitenkin tietoja niistä kasvuun vaikuttavista tekijöistä, joihin viljelijä voi toimenpiteillään vaikuttaa.

ANNALES AGRICULTURAE FENNIAE, VOL. 19: 108—124 (1980)

Seria AGROGEOLOGIA ET -CHIMICA N. 103 — Sarja MAA JA LANNOITUS n:o 103

COMPARISON OF FINE AND COARSE LIMESTONES IN POT AND FIELD EXPERIMENTS

ANTTI JAAKKOLA and RAILI JOKINEN

JAAKKOLA, A. & JOKINEN, R. 1980. **Comparison of fine and coarse limestones in pot and field experiments.** Ann. Agric. Fenn. 19: 108—124. (Agric. Res. Centre, Inst. Agric. Chem. and Phys., SF—31600 Jokioinen, Finland.)

Dolomitic and calcitic limestones ground to two grades of fineness were compared in field and pot experiments. The field experiments were performed on a Gyttja clay, a Fine sand and a Carex peat soil with two liming rates (8 and 16 tons/ha). All soils were acid. The pot experiments were carried out with soils taken from the plough layer of the experimental fields and treated with increasing amounts of the liming materials and their two particle-size fractions. Barley was used during the whole three-year experimental period.

On the basis of the short-term effect on soil acidity measurable in pots half a year after liming and on the field during the two first years, the dolomitic materials were at least one-third less effective than the calcitic. The coarse grindings (38 % of particles <0,15 mm) were about equally inferior to the fine ones (55—64 % <0,15 mm). The fraction which passed through the 0,15 mm sieve was many times more effective than the rest in all the materials.

The final difference between the coarse and fine grindings was maximum 20 per cent, as was the difference between dolomitic and calcitic limestones in the pots, but on the field the difference was somewhat larger. Differences between soils were small.

The extractable magnesium content of soil treated with dolomitic limestone was also dependent on the fineness of the limestone. Differences in crop yield and calcium and magnesium contents were in good agreement with the results referred to above.

Index words: Liming materials, particle-size.

INTRODUCTION

The carbonates of calcium and magnesium most often used as liming material for acid soils dissolve only sparingly in soil water. Hence, their soil-neutralizing effect is known to be dependent on the particle size. In Finland, there are statutes which state that calcitic and dolomitic limestones sold as liming material must be ground so that 50 per cent of the material will pass through a 0,15 mm sieve.

Because of rapidly increasing grinding costs due to rising energy prices the question has arisen of whether it might be possible to reduce the amount of fine material without seriously reducing the overall effect. The industry has suggested a grinding strength which produces materials containing at least 30 per cent <0,15 mm fraction. In addition to lower production costs these materials would have some extra benefits: they would be somewhat easier to spread out, less sensitive to moisture and not as dusty as the present materials.

The aim of this study was to find out how much the liming effect of dolomitic and calcitic limestones is changed due to the reduced grinding suggested by the Finnish lime-producing industry. In order to obtain results directly applicable in practice, pot and field experiments were carried out in addition to chemical soil and plant analyses.

MATERIAL AND METHODS

Liming materials

Some properties of the liming materials studied are given in Table 1. The fine and coarse dolomitic and calcitic limestones were ground from the same respective raw materials. The calcium and magnesium contents were determined by the State Institute of Agricultural Chemistry using the official method which entails dissolution of the elements with hot 1 N HCl. The »neutralizing ability» is calculated as the sum of Ca + 1,65 × Mg. For comparison, the acid neutralized by the materials in a similar treatment was also determined and the result given as equivalent calcium content. Other contents given in Table 1 have been determined in the same acid extracts.

The fine dolomitic and calcitic limestones represent normal materials on the Finnish market. The dolomitic raw material is harder

Table 1. Liming materials.

	Fine dolomitic limestone	Coarse dolomitic limestone	Fine calcitic limestone	Coarse calcitic limestone
Particles <0,15 mm [1]), %	55,0	38,4	64,1	38,1
0,15—0,3 mm , %	16,3	15,9	14,4	15,2
0,3 —0,6 mm , %	15,6	14,6	11,9	14,7
0,6 —2,0 mm , %	11,7	26,1	9,6	28,9
>2,0 mm [1]), %	1,4	5,0	0,0	3,1
Calcium % [1])	20,9	20,0	36,1	34,5
Magnesium % [1])	9,5	9,0	0,73	0,75
Neutralizing ability:				
Ca + 1,65 × Mg % [1])	36,5	34,8	37,3	35,7
acid neutralized equivalent to Ca %	34,3	32,4	35,9	34,9
Phosphorus mg/kg	240	280	80	80
Potassium »	220	270	150	60
Sodium »	50	50	150	120
Iron »	1 730	1 730	1 110	1 070
Manganese »	80	140	390	390
Zinc »	15	14	11	9
Copper »	9	12	8	11

[1]) Determined by the State Institute of Agricultural Chemistry. Other determinations carried out by the Agricultural Research Centre.

than the calcitic one, which has probably led to the latter being finer. The coarser grinding made both materials a little finer than expected. The decrease in the fraction below 0,15 mm is counterbalanced by the increase in the fractions above 0,6 mm in both raw materials. The intermediate fractions seem to have changed very little.

Pure dolomite contains 1,65 times as much calcium as magnesium by weight. Hence, the dolomitic limestones were apparently mixtures of dolomite and calcite in a molar ratio of 3 : 1. The calcitic limestones did not contain magnesium compounds to any marked extent. There were relatively small differences between fine and coarse materials. However, the fine ones were somewhat richer in both calcium and magnesium, probably due to better solubility of the finer particles.

The neutralizing ability determined through acidimetric titration was lower than calculated by the official method. There were evidently some neutral calcium and magnesium compounds besides the carbonates in the liming materials. The difference between the neutralizing abilities determined by different methods did not seem to be dependent on the fineness of the material.

The contents of other elements determined in the coarse materials were in general a little lower than in the finer ones. This is probably caused by the lower solubility due to the larger portion of coarse fractions.

Experimental soils

The effect of liming on soil properties and crop growth depends partly on the soil itself. Different locations with different climates may cause some variation, too. To get an idea of these factors the field experiments for this study were established at three locations on widely differing soils. Pot experiments were carried out with soils taken from the plough layer of the experimental fields. These soils had the following properties:

	Gyttja clay Pernaja	Fine sand Ylistaro	Carex peat Vaala
Particles < 0,002 mm, %	56	18	—
$pH(CaCl_2)$	4,8	4,6	4,2
$pH(H_2O)$	5,3	5,1	5,0

Acid ammonium acetate (pH 4,65) extractable nutrients:

P mg/l	8,0	5,1	8,7
K »	240	110	25
Ca »	1 080	500	800
Mg »	120	50	100

All soils were acid. Their $pH(H_2O)$ was below the mean of all Finnish soils, which is ca. 5,5 (Kurki 1972). Two of the soils were mineral and one an organic soil. The mineral soils differed considerably in their particle-size composition; one had a 56 per cent clay fraction, the other less than 20 per cent. The predominant fraction in the latter soil was very fine sand (0,02—0,06 mm), which comprised 35 per cent.

Of the nutrients, attention should be paid to magnesium, because two of the materials studied contained magnesium in considerable amounts. Only the Fine sand from Ylistaro was so poor in magnesium that the magnesium-fertilizing effect might be likely.

Pot experiment

The liming properties of the four materials to be studied were tested in a three-year pot experiment. These experimental soils were taken from the plough layer of the fields in the experiments reported below. Some properties of the soils are discussed above. A barley variety known to be sensitive to acidity was grown in the pots during three growing seasons.

The plastic 5-litre pots were kept outdoors under normal climatic conditions prevailing in southern Finland (Tikkurila), where the trial was carried out. The pots had a hole in the bottom for drainage. The drained water was collected and reapplied on the soil surface daily. The pots were watered with deionized water when necessary.

The experiment comprised the following treatments: an unlimed control, all four liming materials at rates 6, 12, 18 and 24 g per pot plus 12 g per pot under and above the 0,15 mm fractions of each material. These 25 treatments, three soils and four replications totalled 300 pots in the experiment.

The experiment was established on October 26—27, 1976. The amounts of soil weighed per pot were as follows:

Soil	Gyttja clay	Fine sand	Carex peat
D.M. %	62,8	73,0	49,7
Amount, kg per pot ...	4,2	4,0	3,3

The treatments consisting of the lime additions reported above were performed at the same time. The liming materials were mixed thoroughly with the entire soil in the pots. After mixing the pots were covered with plastic film to prevent evaporation and kept indoors at room temperature for three weeks. On November 19, 1976 the pots were moved outside until the end of the experiment in order to keep them under the influence of the climate. It may be assumed that the soils were frozen for about three months yearly.

The first crop, barley variety Ingrid, was sown on May 9—10, 1977. Sufficient NH_4NO_3, KCl, $Ca(H_2PO_4)_2 \cdot H_2O$, H_3BO_3, $MnSO_4 \cdot H_2O$, $CuSO_4 \cdot 5H_2O$, $ZnSO_4 \cdot 7H_2O$ and $Na_2MoO_4 \cdot 2H_2O$ were mixed with the soil before sowing in order to assure good growth. The crop was harvested at maturity on August 22—26. The grain and straw yields were weighed separately.

The same crop was grown in the two following years. It was also fertilized similarly. The sowing and harvesting dates for those years were: May 17 and August 30—31, 1978, and May 14 and August 20—24, 1979, respectively.

The first-year grain and straw from each pot were analyzed for calcium and magnesium. The determinations were made using atomic absorption spectrometry of acid extract of ashed plant material.

Soil samples were taken yearly from each pot before sowing and after harvest and their pH in 0,01 M $CaCl_2$ suspension was determined. The samples taken after the last harvest, in 1979, were also analyzed for calcium and magnesium extractable in acid ammonium acetate, pH 4,65. The pH was measured in water suspension, too.

Field experiments

Three field experiments were established. They were located in Pernaja, 60°30′N, on Gyttja clay, in Ylistaro, 63 °N, on Fine sand, and in Vaala, 64 °30′N, on Carex peat. The properties of the plough layers are discussed above, because representative samples were used as experimental soils in the pots. The subsoils were also acid. The pH measured in water suspension of the subsoil of the Pernaja, Ylistaro and Vaala fields was 4,2, 4,7 and 4,6, respectively.

The treatments consisted of unlimed controls plus 8 and 16 tons per hectare of the four liming materials. The calcitic and dolomitic limestones were arranged in main plots, the rates 8 and 16 tons/ha in subplots and the fine and coarse grindings in sub-subplots. Each main plot was accompanied by an unlimed control plot. The treatments were replicated four times, each replication in a separate block.

The treatments were spread in autumn 1976. One half of the amount of lime for a plot was spread before, and the other after ploughing. The aim of this method was an even distribution of lime throughout the whole plough layer of a plot.

Varieties of barley known to be sensitive to soil acidity were grown on all fields during the three years, except in 1978 when oats were grown on the Gyttja clay. NPK fertilizers were applied as normal to the crops each spring. Other normal cultivation practices were followed. The grain was harvested with combine harvesters leaving the straw on the plots. The grain yield of each plot was weighed separately. The oats sown on Pernaja Gyttja clay in 1978 were very badly lodged and the yields were not weighed. The fields were ploughed each autumn. The ploughing depth was ca. 20 cm.

Soil samples representing the plough layer of each plot were taken in autumn 1976 before the treatments and in the following three years after harvesting the crop. Soil pH in water suspension was measured, and calcium and magnesium extractable in acid ammonium acetate, pH 4,65, was determined.

RESULTS

Pot experiments

The liming materials were mixed with the soil in late autumn. The following spring the soil pH had clearly been changed by the lime (Fig. 1). The calcitic limestone was more effective than the dolomitic and the finer grindings were more effective than the coarser. The response of soil pH to increasing amounts of all liming materials was almost linear. However, the final increments tended to have a slightly lower effect than the first. The soils responded differently to liming. The response in Gyttja clay was least, in Carex peat greatest. The relative differences between liming materials seemed to be constant in all three soils. Coarse calcitic limestone was always as effective as fine dolomitic limestone. The effect of a liming rate of 24 g per pot of coarse dolomitic limestone was similar to about 10 g per pot of fine calcitic limestone in all soils.

The differences between liming materials decreased during the experiment. In spring 1978, after 1,5 years of experiment, these differences were clearly narrower than earlier in the Gyttja clay and the Fine sand. This also applies to differences between raw materials and between grindings. In Carex peat the situation was different. The effect of grindings of the same raw material approached each other here, too, but difference between calcitic and dolomitic limestones increased somewhat.

In the last year the differences were even narrower, also in the Carex peat. If liming materials are compared on the basis of results from autumn 1979, after 3 years of experiment, the effect of 24 g per pot of the least effective material, coarse dolomitic limestone, corresponded to about 18 g per pot of the most effective material, fine calcitic limestone. There were no marked differences between the soils.

The lowest part of Fig. 1 shows the change in soil pH between 1977 and 1979. The values shown are differences between the spring and autumn means of pH values in the years mentioned. The differences were generally small. Increasing amounts of fine calcitic limestone were no longer able to affect the pH after the first year. Coarser grindings of the same raw material as well as both grindings of dolomitic limestone continued to raise the pH during this period. There were no clear differences between these materials. However, the effect of coarse dolomitic limestone seemed to be a little superior to the effect of the fine grinding.

The treatments also included application of two fractions, below and above 0,15 mm, of each liming material. The aim of these treatments was to compare the relative efficiency

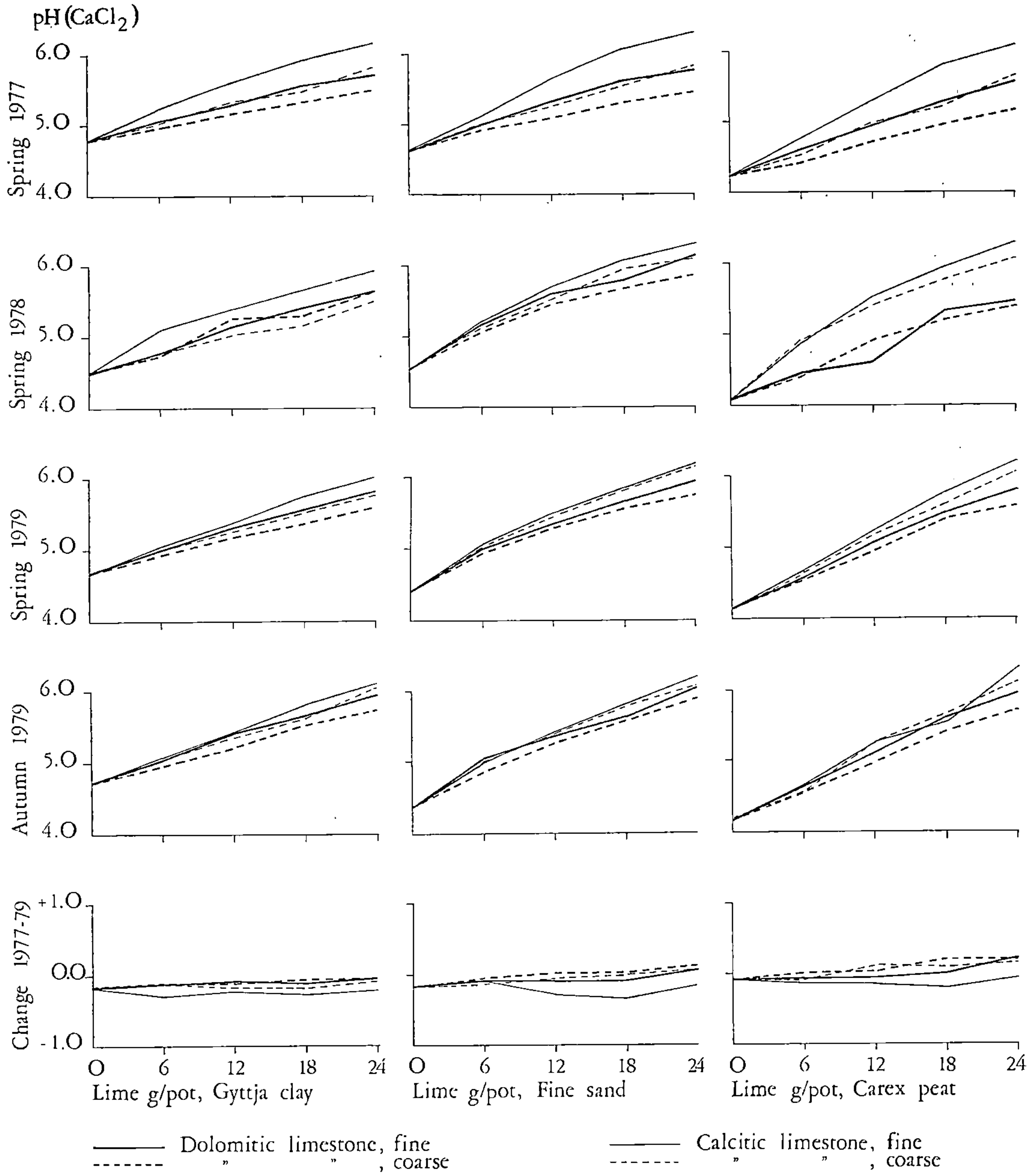

Fig. 1. Effect on soil pH($CaCl_2$) of increasing amounts of the liming materials mixed with soil in autumn 1976.

of the fractions. The comparison was made by determining through interpolation the amount of unsieved lime which had the same effect as the fraction. Since no essential differences were observed between the soils, their means were calculated. The ratio of the efficiency of the finer fraction to that of the coarser was as follows:

	Spring 1977	Autumn 1979
Dolomitic limestone, fine	4,4	1,1
» » , coarse	6,7	1,2
Calcitic limestone, fine	4,8	1,2
» » , coarse	5,8	1,2

Three years after application the fraction finer than 0,15 mm was only 10—20 per cent more effective than the coarser one. However, the efficiency of the fraction determined in the spring following application in late autumn differed considerably. The finer fraction was 4,4—6,7 times as effective as the coarser one. The fractions of the coarse grindings differed more than those of the fine grindings. The main reason for this was probably the different particle-size composition of the $>0,15$ mm fractions of fine and coarse grindings. As shown in Table 1, half of the particles of coarse limestones unable to pass through a 0,15 mm sieve were over 0,6 mm in diameter, while the corresponding portion of fine limestones was only about a quarter. No great differences between raw materials were found in this respect.

The absolute effect on soil pH of the fraction which passed through the 0,15 mm sieve did not significantly depend on the grinding, while different raw material caused some differences. The finer fraction of the calcitic limestone was more effective than that of the dolomitic, especially in the beginning of the experiment, but a slight difference was however still detectable three years after application. The following means of pH of the three soils were obtained:

Fraction			Spring 1977	Autumn 1979
$<0,15$ mm of	fine	dolomitic limestone	5,5	5,4
»	coarse	» »	5,5	5,2
»	fine	calcitic limestone ..	5,9	5,6
»	coarse	» » ..	5,8	5,4

The liming considerably affected crop growth only on the Fine sand (Fig. 2). The main effect was reached with the smallest rate applied: 6 grams per pot of liming materials. No differences were found between the materials. The liming effect of the least effective material, the coarse dolomitic limestone, was sufficient even at the lowest rate and no real benefit was gained by using more effective materials or this material at higher rates. The low content of extractable magnesium in this soil seemed to have been sufficient although the lowest rate of calcitic limestone (6 g/pot) contained only 45 mg/pot of magnesium.

While marked responses were found only on the Fine sand, some slight but significant differences were obtained on other soils, too. The total yield of grain and straw over the three years responded positively to the application of the fine calcitic limestone. Also the difference between coarse dolomitic and fine calcitic limestones at their highest rate was statistically significant ($P = 0,01$). Similar differences were also apparent in the grain yields of all three years of experiment.

The first grain yield from the Gyttja clay also responded slightly but significantly to liming. A significant ($P = 0,05$) effect was reached with 12 g/pot of fine calcitic limestone, 18 g/pot coarse calcitic limestone and 24 g/pot of both grindings of dolomitic limestone. These findings are in quite good agreement with the pH responses (cf. Fig. 1, spring 1977).

The calcium contents in both the first-year grain and straw were increased by liming the Gyttja clay and Carex peat with calcitic limestone (Fig. 3). No significant difference was observed between the grindings. Dolomitic limestone also increased the calcium contents slightly, but the difference was not statistically significant ($P = 0,05$). On the unlimed Fine sand the calcium contents were increased due to poor growth. At the lowest rate of liming the contents were lowered to normal level. The application of calcitic limestone at higher rates somewhat raised the content in straw.

The magnesium contents in grain did not respond significantly to the treatments in any soil (Fig. 3). However, it is obvious that the

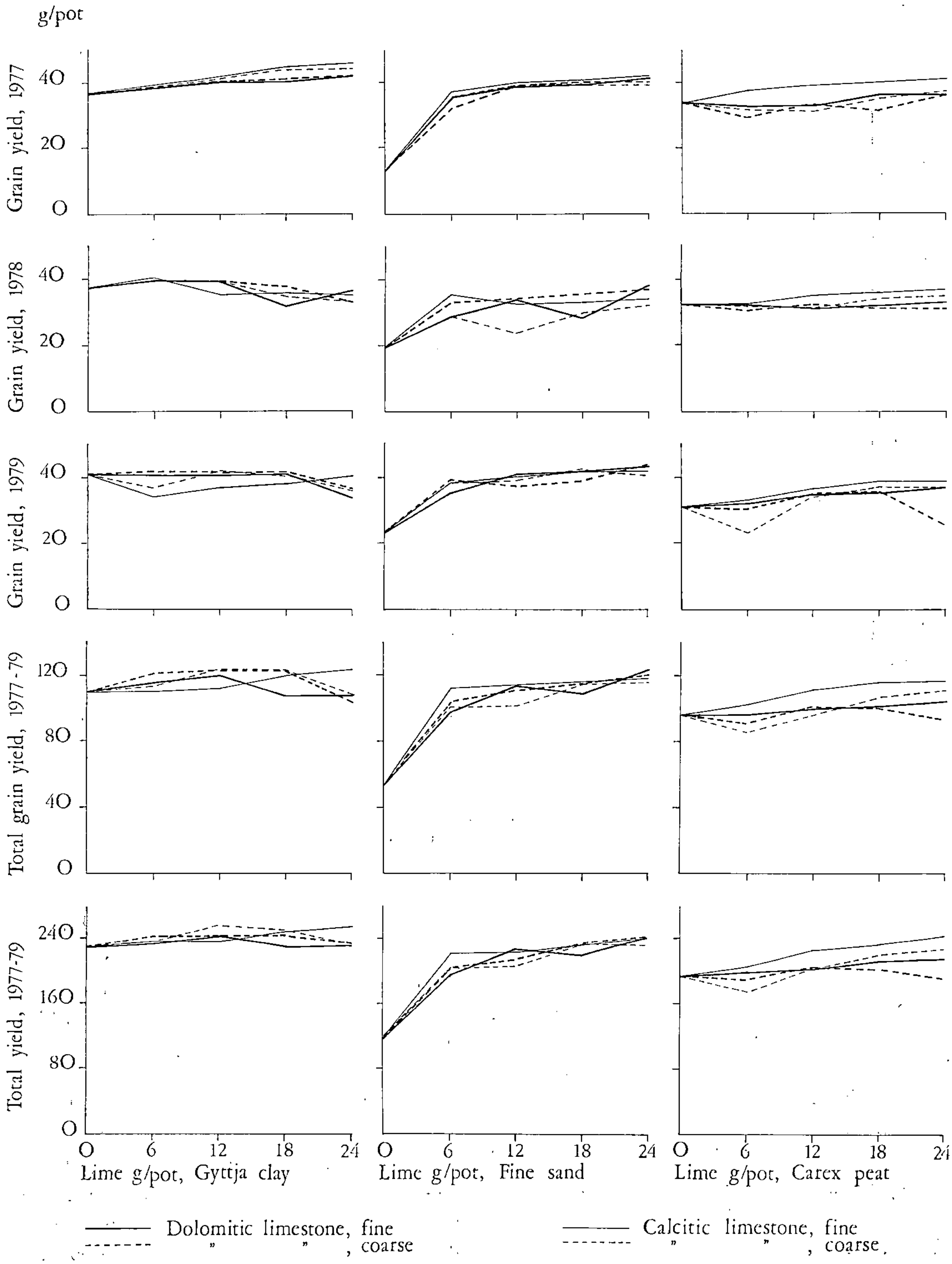

Fig. 2. Effect on barley growth of increasing amounts of the liming materials mixed with soil in autumn 1976.

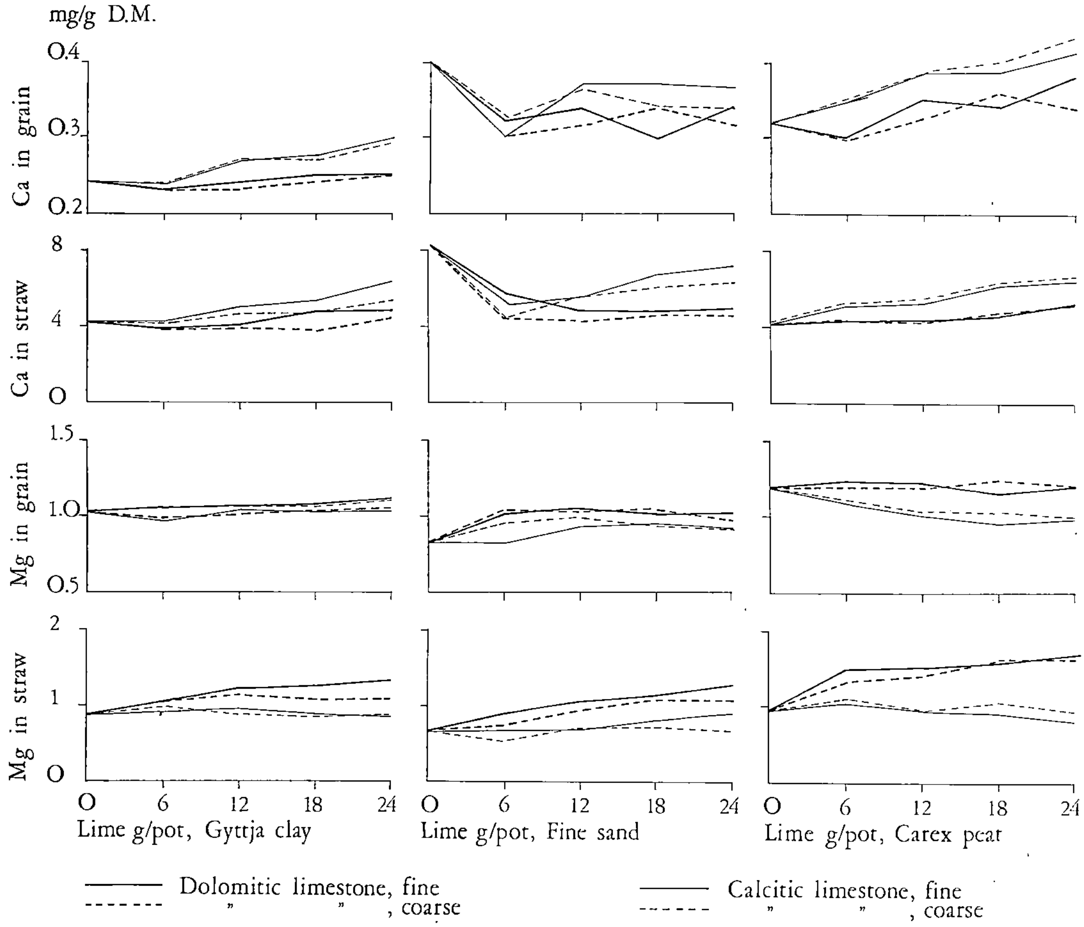

Fig. 3. Effect on calcium and magnesium content in first-year barley grain and straw of increasing amounts of the liming materials.

calcitic limestone had a slightly depressive effect on the grain magnesium, especially on Carex peat. The magnesium contents in straw were increased by application of dolomitic limestone; the calcitic limestone had no effect. No significant difference was observed between the grindings of dolomitic limestone.

The pH values measured in water suspension at the end of the experiment in autumn 1979 (Fig. 4) showed similar response to the treatments as the pH determined in $CaCl_2$ suspension (cf. Fig. 1). The calcium extractable from soil with acid ammonium acetate solution (pH 4,65) was clearly increased due to liming. The difference between calcitic and dolomitic limestones was proportional to their calcium contents (cf. Table 1). The apparent slight superiority of fine grindings was not statistically significant (P = 0,05).

The dolomitic limestone very clearly raised the extractable magnesium content of the soils. The calcitic limestone had no effect. The extractable magnesium content of the Fine sand and Carex peat dropped during the experiment to 20—40 mg/l when no magnesium-containing liming material had been added. Some symptoms of magnesium deficiency were observed in the leaves of three-week-old seedlings in some of

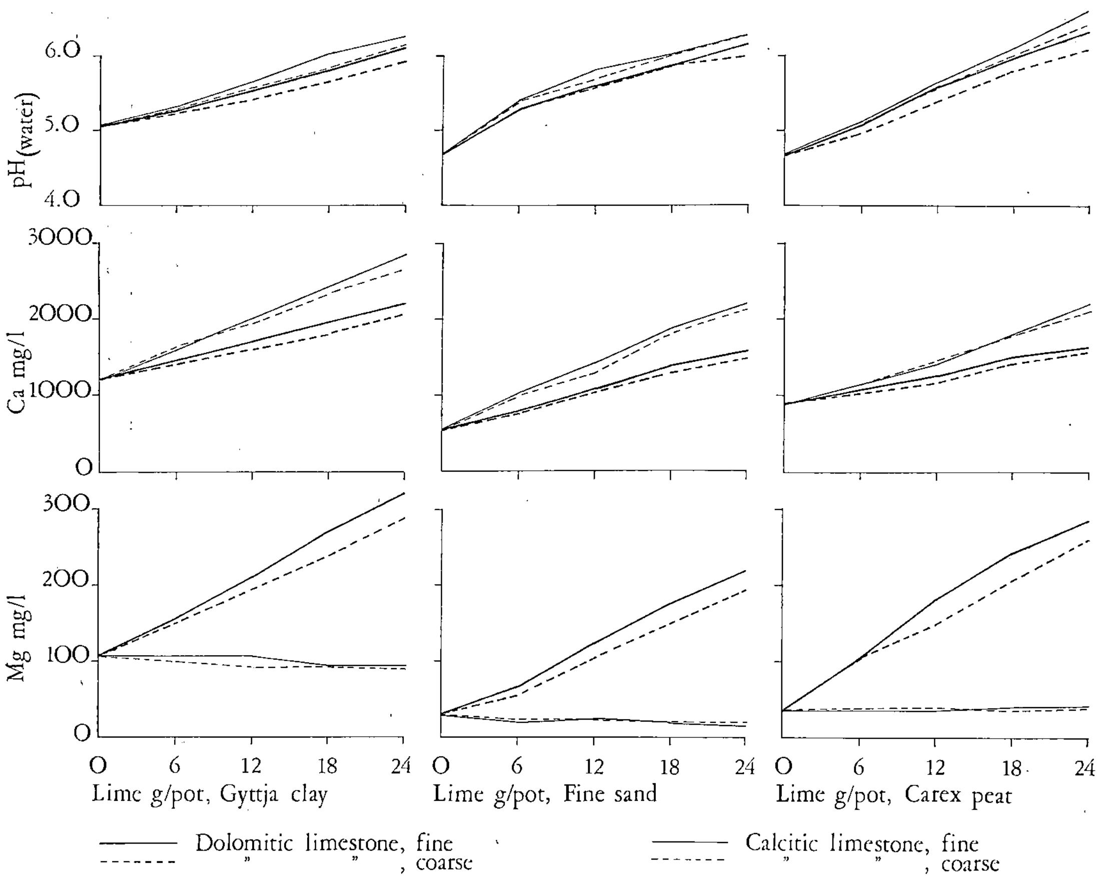

Fig. 4. Effect on soil pH(water) and extractable calcium and magnesium of increasing amounts of the liming materials mixed with soil three years earlier.

the pots. However, no reduction in grain or straw yield due to lack of magnesium was observed. On the other hand, it was not possible to prove that the yield depression in the unlimed pots was caused entirely by acidity. The magnesium-deficiency symptoms were clearest in these pots. The extractable magnesium in soil was 10—20 per cent lower three years after application of the coarse dolomitic limestone than after application of the fine dolomitic limestone.

The soil contents of extractable calcium and magnesium were given in milligrams per litre of air-dry soil. Since the volume of soil in the air-dry state contained in the pots is unknown, it is not possible to evaluate the portion of the applied amount that was recovered in extractable form. It is obvious that the recovery of calcium was almost complete. Assuming the calcium recovery after application of fine calcitic limestone to be 100 per cent, the magnesium recovery after fine dolomitic limestone application seems to be only about 50 per cent.

Field experiments

The barley grown on Gyttja clay in Pernaja in 1977 was very severely lodged. The higher

Table 2. The grain yields (kg/ha at 15 per cent moisture) of barley in 1977—79 on Gyttja clay soil limed in 1976 with different rates of dolomitic and calcitic limestones ground to varying fineness.

	1977	1978	1979	Total (2 years)
Dolomitic limestone				
Control (unlimed)	2 990	not weighed	4 430	7 420
8 tons/ha, fine ..	2 860	» »	4 440	7 300
» » , coarse	2 720	» »	4 500	7 220
16 » , fine ..	2 960	» »	4 430	7 390
» » , coarse	3 070	» »	4 370	7 440
Calcitic limestone				
Control (unlimed)	2 860	not weighed	4 560	7 420
8 tons/ha, fine ..	2 710	» »	3 670	6 380
» » , coarse	2 690	» »	4 340	7 030
16 » , fine ..	2 370	» »	4 640	7 010
» » , coarse	2 540	» »	4 120	6 660

Significant F values (analysis of variance without controls):

Raw materials	37,47**		—	—

Table 3. The grain yields (kg/ha at 15 per cent moisture) of barley in 1977—79 on Fine sand soil limed in 1976 with different rates of dolomitic and calcitic limestones ground to varying fineness.

	1977	1978	1979	Total (3 years)
Dolomitic limestone				
Control (unlimed)	3 850	1 530	2 100	7 480
8 tons/ha, fine ..	4 710	2 620	3 590	10 920
» » , coarse	4 520	2 260	3 570	10 350
16 » , fine ..	4 620	2 840	3 560	11 020
» » , coarse	4 450	2 680	3 410	10 540
Calcitic limestone				
Control (unlimed)	3 730	1 230	2 260	7 220
8 tons/ha, fine ..	4 610	2 490	3 540	10 640
» » , coarse	4 530	2 350	3 490	10 370
16 » , fine ..	4 500	2 750	3 770	11 020
» » , coarse	4 620	2 520	3 380	10 520

Significant F values (analysis of variance without controls):

Grindings (fine-coarse) ...	—	11,20**	—	—

rate (16 tons/ha) of calcitic limestone apparently had a positive effect on the growth but a negative effect on the grain yield due to increased lodging (Table 2). The fine grinding seemed to be a little more efficient than the coarse one. No other treatments differed from each other or from the unlimed controls.

The oats grown in 1978 failed because of lodging and were not weighed. The barley grown in the last experimental year did not respond to the treatments. Neither was the total grain yield of 1977 and 1979 significantly affected by the treatments.

The field, although acid, seemed to be in rather good condition without liming. The barley grown in pots filled with soil from this field did not clearly respond to liming. The possible growth-promoting effect of the higher rate of calcitic limestone on the field may have been caused by increased mobilization of nitrogen. Such an effect would not have been so pronounced in the pot experiment, because relatively more fertilizer nitrogen was given.

The second experimental field in Ylistaro on Fine sand soil was, according to the pot experiment, potentially too acid for sufficient growth of acidity-sensitive barley varieties. The conditions for finding differences in growth due to liming were therefore better than on the field in Pernaja. In fact, the barley grain yield was increased by liming in all experimental years on the field (Table 3). In the first year the increase was relatively small and no differences existed between raw materials, lime

Table 4. The grain yields (kg/ha at 15 per cent moisture) of barley in 1977—79 on Carex peat soil limed in 1976 with different rates of dolomitic and calcitic limestones ground to varying fineness.

	1977	1978	1979	Total (3 years)
Dolomitic limestone				
Control (unlimed)	1 210	2 050	2 620	5 880
8 tons/ha, fine ..	2 230	3 000	2 990	8 220
» » , coarse	2 290	2 970	3 280	8 540
16 » , fine ..	2 000	2 360	2 740	7 100
» » , coarse	1 950	2 730	2 870	7 550
Calcitic limestone				
Control (unlimed)	1 190	1 680	2 320	5 190
8 tons/ha, fine ..	2 070	2 540	2 890	7 500
» » , coarse	2 110	2 900	3 130	8 140
16 » , fine ..	1 940	2 870	3 140	7 950
» » , coarse	1 840	2 920	3 160	7 920

No significant F values (analysis of variance without controls).

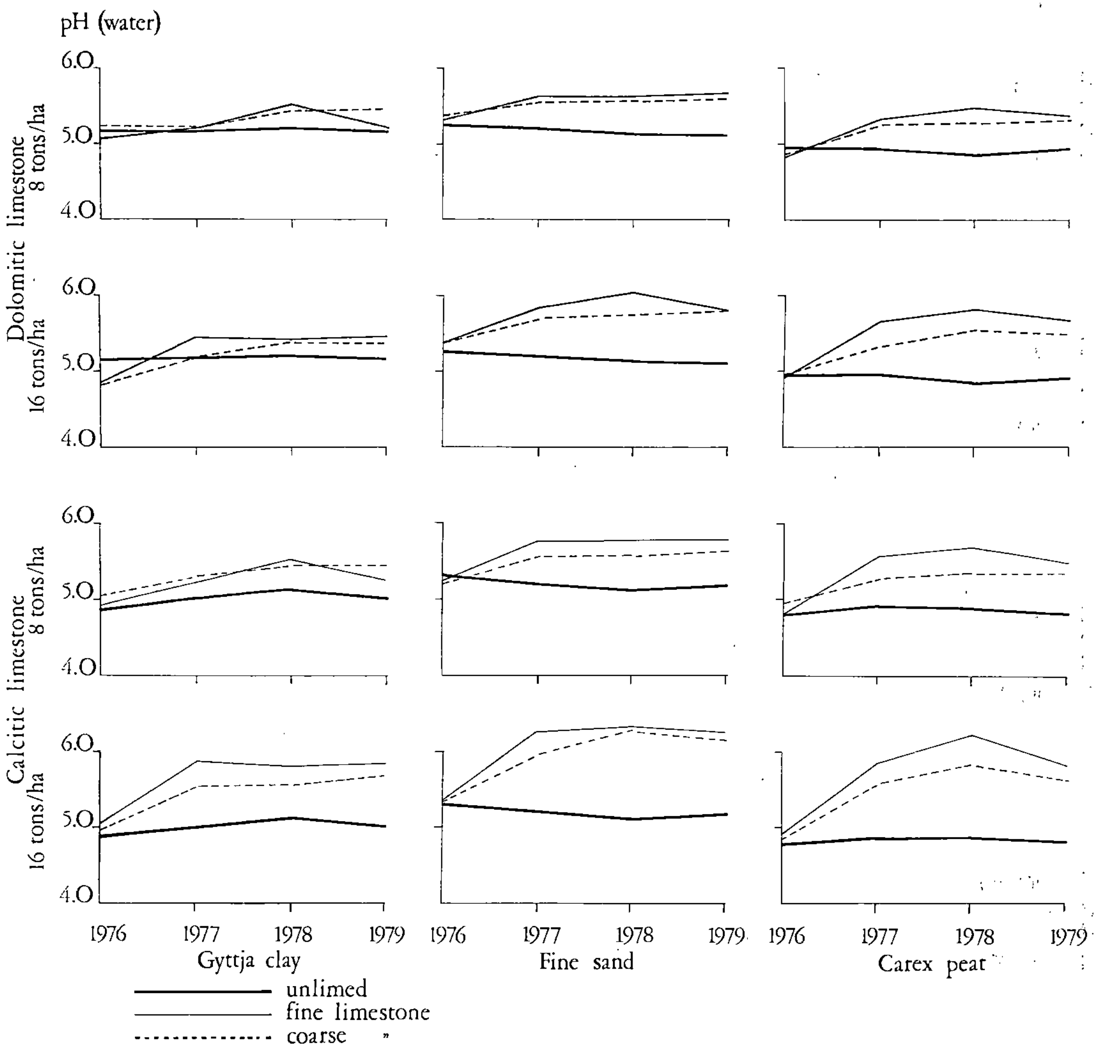

Fig. 5. Changes in soil pH(water) measured after harvest in different treatments in the field trials.

rates or grindings. In the second year (1978) the yield increase due to liming was much more pronounced. Neither the dolomitic and calcitic limestones nor the liming rates deviated significantly from each other (P = 0,05). Apparently however, as shown by the means in Table 3, the higher liming rate caused higher yields, but great random variation among the subplots prevented showing the differences to be significant. The fine grinding was significantly (P = 0,01) superior to the coarse one. Because no substantial differences existed between the dolomitic and calcitic limestones, the following means may help to show the effect of liming and the difference between the grindings:

unlimed				1 380	kg/ha	grain
8 tons/ha	fine	limestone	....	2 560	»	»
» »	coarse	»	....	2 310	»	»
16 »	fine	»	....	2 800	»	»
» »	coarse	»	....	2 600	»	»

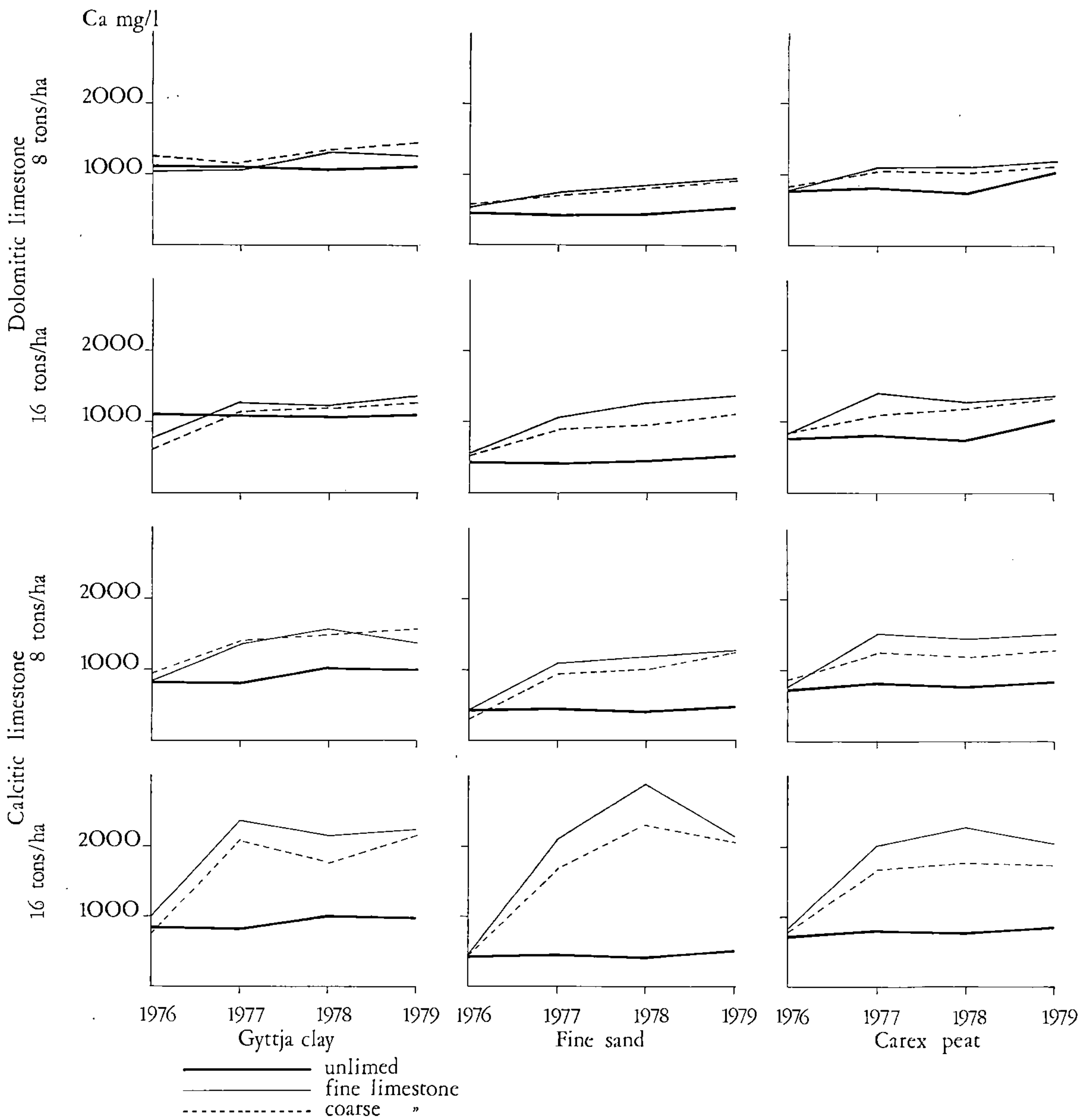

Fig. 6. Changes of extractable calcium in soil in different treatments in the field trials.

The differences between the grindings were 200—250 kg/ha or nearly as much as between the rates. These differences were 240—290 kg/ha. An almost double liming rate thus seemed to be necessary to compensate for the decrease in efficiency due to leaving the limestone coarser during grinding.

In the third year (1979), the liming effect was again very marked. However, even the slightest liming seemed to be sufficient, and no additional benefit was gained by increasing the rate or choosing another liming material. Hence no conclusions could be drawn about the differences in the efficiency of the liming materials.

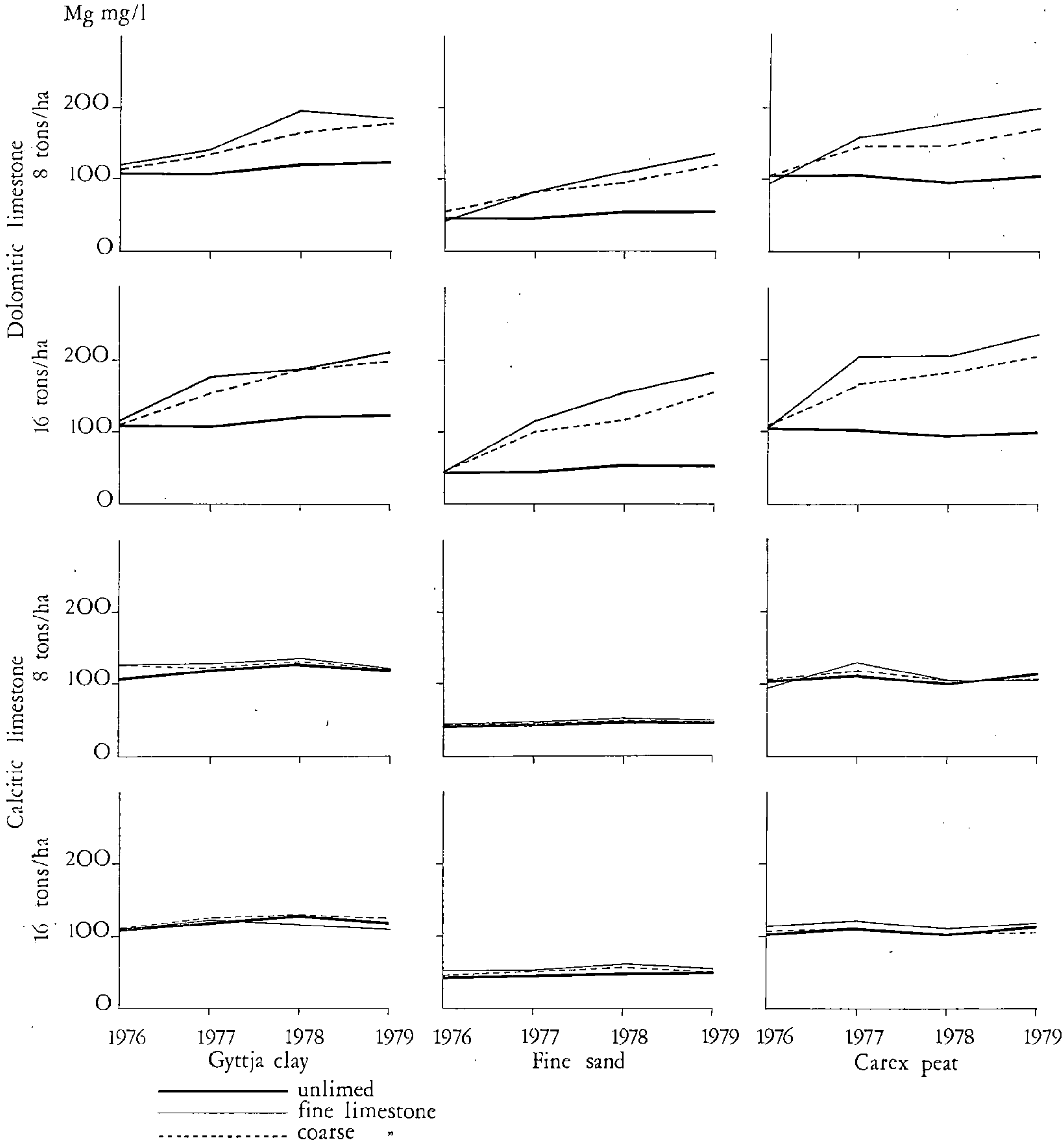

Fig. 7. Changes in extractable magnesium in soil in different treatments in the field trials.

A very marked yield-increasing effect of liming was also detectable in the total yields over the entire three-year period. The slight apparent differences between liming rates and materials were not significant. No evidence of magnesium deficiency was observed in any year.

In the third experiment on the Carex peat in Vaala liming also had a marked yield-increasing effect on barley (Table 4). However, the differences between liming materials and rates were not significant. Hence, here again even the lowest rate of least efficient liming material was able to bring about practically all the possible liming benefit.

The changes in pH (water) in the plough layer were followed by determining it in samples taken just before liming and after every harvest (Fig. 5). The pH of the Fine sand and Carex peat responded to liming much more than the pH of Gyttja clay. The differences between liming rates and materials were also larger in the former soils. The means of differences between the fine and coarse grindings for all three soils were as follows:

	1977	1978	1979
Dolomitic limestone, 8 tons/ha	0,0	0,1	0,0
» » , 16 »	0,2	0,2	0,1
Calcitic limestone, 8 »	0,1	0,2	0,0
» » , 16 »	0,3	0,3	0,1

The differences were markedly smaller in the third year than in the first two years. As can be seen in Fig. 5, the pH level in soil limed with the fine materials tended to drop during the last experimental year. In 1978 when the liming effect was apparently largest, 8 tons/ha of fine dolomitic and calcitic limestones increased the pH of the three experimental soils an average of 0,5 and 0,6 units, respectively. The rate of 16 tons/ha raised the pH 0,7 and 1,1 units, respectively. The coarser grinding reduced these increases by one third or one quarter. As pointed out above, this difference was much smaller in the following year.

The extractable calcium contents of soil (Fig. 6) were closely correlated with pH. The differences between the grindings of the same raw material were also similar. The increases in contents and their differences after application of calcitic limestone were larger than after application of dolomitic limestone. The decrease in the effect of fine calcitic limestone during the last year was very marked in the Fine sand at the higher liming rate. No similar decrease was observed when dolomitic limestone had been used. This may be evidence of slower dissolution and lower leaching of dolomitic calcium.

The extractable magnesium contents of soil (Fig. 7) were affected by the dolomitic limestones only. The contents tended to increase throughout the entire experimental period, demonstrating the slow dissolution of dolomite. The differences between the grindings were clear on the Fine sand and the Carex peat, especially at the higher liming rate in the second and third experimental years. The reduction in effect on soil magnesium in these two soils due to coarser grinding was 20—30 per cent at the end of the experiment.

DISCUSSION

The calcite has been proved to be more rapidly soluble than the dolomite in many investigations (e.g. Shaw and Robinson 1959, Anderson 1968, Matzel and Ansorge 1971, Persson 1974). The difference was clear in this study, too. In the pot experiment half a year after mixing the limes with soil, the pH-increasing effect of the dolomitic limestone was no more than two-thirds of that of the calcitic one. It must be borne in mind that the dolomitic limestone studied here was not pure dolomite. One quarter of its acid-neutralizing ability depended on calcite. The dolomite part of the material must have had an even slower effect than concluded above. The final difference after three years was, however, actually less or no more than 20 per cent. The difference was clearly reduced in the two mineral soils in the beginning of the second growing season (1,5 years after application), while in the peat soil the difference first began to decrease during the second half of the three-year experimental period.

Half a year after mixing the lime with soil, the coarser materials remained far behind the finer ones in their effect on pH in the pots. The difference was as large as that between the dolomitic and calcitic limestones under study. So, in this short period, only the <0,15 mm fraction seemed to have reacted with the soil. In the fine materials, this fraction made up 55—64 per cent; in the coarse limestone it was 38 per cent. This was further proved by comparing the below and above 0,15 mm fractions of each liming material. The former showed an efficiency many times greater than the latter. The fraction above 0,15 mm sieved from the coarse materials was relatively more inefficient than that fraction of the fine materials. This is accounted for by the fact that the former contained very much more >0,6 mm fraction than the latter. The very markedly decreasing reactivity of fractions with increasing particle size has been observed in numerous investigations (e.g. Gibaly and Axley 1955, Motto and Melsted 1960, Anderson 1968, Matzel and Ansorge 1971, Persson 1974). However, the difference between fine and coarse grindings decreased quite rapidly and was, at the end of the pot experiment, no more than 10—20 per cent. The difference between the fractions above and below 0,15 mm was also reduced to only 10—20 per cent.

The differences in soil pH at the end of the experimental period were similar on the fields and in the pots. However, some dissimilarities did appear, as shown by the final mean responses of soil pH(water) to liming with different materials

	Dolomitic limestone fine	Dolomitic limestone coarse	Calcitic limestone fine	Calcitic limestone coarse
12 g/pot	+0,8	+0,7	+0,9	+0,8
16 tons/ha	+0,6	+0,5	+1,0	+0,8

Fine and coarse materials behaved quite similarly in relation to each other in both types of experiment. The inferiority of the dolomitic limestone to the calcitic was more pronounced on the field than in the pots. The development of the differences was much more rapid in the pots than on the field. In the pots they had actually reached their final levels in the beginning of the second year, while on the field they might possibly have changed after the experimental period. According to earlier studies (e.g. Jaakkola et al. 1977), the pH differences due to liming were expected to last much longer than these experiments showed.

Another potentially important property of soil changed by liming was its extractable magnesium content. This was effected by dolomitic limestones only, due to the lack of magnesium in the calcitic material. The final average changes (mg/l) in the pots and on the field were very similar, as shown below:

	Dolomitic limestone fine	Dolomitic limestone coarse
12 g/pot	+115	+90
16 tons/ha	+117	+94

The response on the field did not develop at once. After the first growing season the responses were 80 and 52 mg/l for fine and coarse materials, respectively.

The yield results confirmed the findings reported above. Unfortunately very slight liming was sufficient to cause the final yield increase, and very few differences between the materials could be shown.

Apparently, the effects of liming would have lasted a very long time beyond the experimental period and during this time the differences may have changed: probably becoming narrower. The final difference between the coarse and fine grindings as well as dolomitic and calcitic limestones was not clearly shown by this study, but in their short-term effect the coarse materials were markedly inferior to the fine ones. Because the dolomitic limestone was clearly less effective than the calcitic material, the fine grinding of the former is particularly important.

Acknowledgement. We wish to express our gratitude to Kalkitusyhdistys (Association for liming) for providing the liming materials studied and other valuable cooperation.

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SELOSTUS

Hienon ja karkean maanparannuskalkin vertailu astia- ja kenttäkokeilla

ANTTI JAAKKOLA ja RAILI JOKINEN

Maatalouden tutkimuskeskus ja Helsingin yliopisto

Koesarjassa verrattiin kahteen eri hienousasteeseen jauhetun dolomiittikalkin ja kalkkikivijauheen vaikutusta maahan ja ohran kasvuun. Koekentät sijäitsivat liejusavella, hietamaalla ja saraturvemaalla. Koemaat olivat happamia. Kalkkimäärät olivat 8 ja 16 t/ha. Astiakoemaina olivat koekenttien kyntökerrosta edustavat maaerät. Koejäseninä olivat nousevat kalkkimäärät sekä kustakin kalkista seulotut alle ja yli 0,15 mm fraktiot. Kokeet kestivät kolme vuotta.

Dolomiittikalkin lyhytaikainen vaikutus maan happamuuteen oli vähintään kolmanneksen vähäisempi kuin kalkkikivijauheen. Karkeaksi jauhetut kalkit (38 % alle 0,15 mm hiukkasia) olivat vaikutukseltaan saman verran hienoksi jauhettuja (55—64 % alle 0,15 mm) heikompia. Seulan (silmäkoko 0,15 mm) läpäisevä aines oli useita kertoja tehokkaampaa kuin seulalle jäänyt. Tämä lyhytaikainen vaikutus oli mitattavissa astiakokeessa puoli vuotta kalkituksen jälkeen. Kenttäkokeissa se kesti kaksi vuotta.

Karkean ja hienon kalkin välinen ero kokeiden päättyessä oli korkeintaan 20 prosenttia. Dolomiittikalkin ja kalkkikivijauheen välinen ero oli samansuuruinen astiakokeessa, mutta kenttäkokeissa se oli yhä vähän suurempi. Oleellisia eroja koemaiden välillä ei ollut.

Hieno dolomiittikalkki nosti maan liukoisen magnesiumin pitoisuutta enemmän kuin karkea. Tutkittavien kalkkien erilaiset vaikutukset sadon määrään sekä kalsium- ja magnesiumpitoisuuteen olivat selitettävissä edellä selostettujen havaintojen perusteella.

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Seria AGRICULTURA N. 63 — Sarja PELTOVILJELY n:o 63

DIFFERENT NITROGEN FERTILIZERS ON MEADOW FESCUE LEY

ERKKI HUOKUNA and JUHANI LAPIOLAHTI

HUOKUNA, E. & LAPIOLAHTI, J. 1980. **Different nitrogen fertilizers on meadow fescue ley.** Ann. Agric. Fenn. 19: 125—130. (Agric. Res. Centre, South Savo Exp. Sta, SF-50600 Mikkeli 60, Finland.)

Three nitrogen fertilizers, nitrochalk, calcium ammonium nitrate (Oulu saltpetre) and urea were compared using three dressing levels on fine sandy soil with pure sown meadow fescue sward during the periods 1971—73. Calcium ammonium nitrate gave the highest average dry matter yield, 8620 kg/ha. Differences between fertilizers were small and not significant. Nitrochalk was the best protein producer, urea the poorest. The effects of different fertilizers on the mineral content of the herbage were negligible; nitrochalk increased the Ca and Oulu saltpetre the Mg content of the herbage.

During the three-year experimental period, nitrochalk increased the pH value of the soil. Oulu saltpetre and urea decreased it a little when used in smaller amounts and decreased it further with the highest (450 kg/ha/yr) nitrogen dressings. All differences between the various effects of the compared fertilizers were small. Urea was concluded to be a recommendable fertilizer considering the price of nitrogen.

Index words: Nitrogen fertilizing, meadow fescue, minerals in forage.

INTRODUCTION

The very rapid increase in the rates of nitrogen fertilizing of grasslands in the last decade prompted this investigation into the effect of different fertilizers under northern conditions. Several scientists (LAGERROTH 1957, SALONEN 1958 and RAAVE 1962) have shown that different kinds of nitrogen fertilizers have different effects on the yield and soil. Calcium nitrate and calcium ammonium nitrate seem to be good fertilizers. Calcium ammonium nitrate is especially suitable on grasslands and calcium nitrate on cereals (SALONEN 1958). Ammonium sulphate and urea have given poorer results. However, as urea is still the cheapest form of solid nitrogen it was interesting to study the reaction of urea when used in high quantities on grassland.

MATERIAL AND METHODS

This study was conducted in 1971—73 at the South Savo Experimental Station at Mikkeli in Central Finland. The soil was fine sand with about 3 % humus in the top soil. The other soil property values in 1970 were: pH (H_2O) 6,35, Ca 1750, K 270, P 11,2 and Mg 69 mg/l. The sward was pure meadow fescue, variety Paavo. It was sown under nurse crop in 1970, seed rate 25 kg/ha. In 1971, 500 kg/ha superphosphate (9 % P) was given and in 1972—73 300 kg/ha was given as one dressing in spring. Potassium (60 % K_2O) was spread every year at a rate of 3 × 75 kg/ha; the first application in spring, the second and third after the first and second cuts, respectively. The nitrogen fertilizers used were nitrochalk (calcium nitrate which contained 15,5 % nitrate nitrogen and 18 % Ca), Oulu saltpetre (calcium ammonium nitrate containing 13 % ammonium + 13 % nitrate nitrogen as well as 6 % Ca and 3 % Mg), and urea (which contained 46 % nitrogen).

The nitrogen dressing levels (N levels) were 150, 300 and 450 kg/ha N spread in three equal dressings at the same time as potassium. The experiment was set up using 4 replicates of split plot randomized blocks.

The crop was harvested at the beginning of the heading stage, three times in 1971—72 and only twice in 1973 due to severe drought in the late summer. Analyses were made from grass samples to determine the content of dry matter, total nitrogen, K, P, Ca and Mg. Soil samples were taken from each plot at the end of the experimental period.

The winters of 1970/71 and 1971/72 were long — from October to the end of April with deep snow (70 cm) and shallow ground frost (10 cm). The winter of 1972/73 was shorter than usual — mild with shallow snow cover (15 cm) and 30 cm deep ground frost.

Rainfall during the growing season (May—August) in 1971, 1972 and 1973 was 208, 252 and 175 mm, respectively. Only in 1973 were July and August dry. Temperatures were a little higher than average in nearly every summer month during the whole experimental period.

RESULTS

Condition of the swards

The plant density of the swards was good in the beginning of the experiment. There were, however, fewer tillers per square metre on the N-450 plots than on the others in the first cut. This phenomenon was accentuated in the second and third years. The swards thinned during the winters, and also during the summers on the highest N-level plots.

In 1972 and 1973, the average tiller numbers/m² were as follows:

	1972	1973
N fertilizing 150 kg/ha	2 970	1 230
» 300 »	2 650	840
» 450 »	2 390	760

The very drastic drop in plant density from the second to the third year was due to winter damage and drought in July 1973, when the swards were unable to recover as usual. There were no differences in density caused by the different fertilizers. The open patches soon filled with weeds and voluntary white clover. The proportion of weeds in the yield was about 5 % in 1971 and 1972 and 15—23 % in 1973; 15 % on 150 and 300 kg/ha plots and 23 % on 450 kg/ha plots. The proportion of white clover was 15 % on the 150 kg/ha plots in 1973 and on the others only 0—1 %. The most common weeds were *Taraxacum* sp. and *Capsella bursa pastoris*. The proportion of the latter was highest on the 450 kg/ha plots.

Table 1. Meadow fescue dry matter yields and percentages in 1971—73.

Fertilizers *)	kg/ha	%	Nitrogen levels **)	kg/ha	%
Oulu saltpetre ..	8 620	19,2	150	7 220	21,0
Nitrochalk	8 290	19,2	300	9 000	19,3
Urea	8 370	19,6	450	9 060	17,6

*) Average of three levels.
**) Average of all fertilizers.

Yields

Dry matter content of the herbage was on an average highest in the urea treatments but the difference between the other fertilizers was small (Table 1). Dry matter percentage varied with the levels of nitrogen. An increase of 50 kg/ha N per cut resulted in a drop of 1,7 percentage units in dry matter.

Herbage yields were highest in the first year: 11 000—12 000 kg/ha dry matter. In 1972 the level was about 9 000 and 1973 only 7 000 kg/ha when two cuts were taken. The differences were statistically significant only between N levels (F value 15,40*). There were no distinct differences between the fertilizers in different cuts or years. The increase in dry matter yield per kg N was 11,9 kg between levels 150 and 300 kg/ha. Nitrogen fertilizing over 300 kg/ha produced no response in the yield.

Crude protein

The differences in crude protein (cp) yields between N levels were highly significant (F value 30,07**). Urea gave a significantly lower crude protein yield than the other fertilizers. The highest crude protein percentage was from the nitrochalk treatment and the lowest from urea (Table 2). The differences in cp percentages between fertilizers were nearly the same on every N levels. Protein content was highest in the third and lowest in the second cut. Nitrogen fertilizing with 50 kg/ha/cut resulted in 3,2 units of crude protein content of dry matter lower than dressing with 100 kg, and 150 kg/ha/cut gave 5,1 units higher than with 100 kg. The highest cp content was recorded in the last cut of the season and the lowest in the second, midsummer cut. The content was very low in exceptionally dry summers.

Crude protein yields were highest in the first cut and lowest in the third cut due to reduction in herbage yield. Urea gave a significantly lower protein yield than nitrochalk or Oulu saltpetre. The increase in crude protein produced per kg N was 3,4 kg between treatments of 150—300 kg/ha and 3,2 kg between treatments of 300—450 kg/ha N fertilizing.

Minerals in forage

There was a significant difference in potassium content of the herbage between nitrochalk and the other fertilizers. Differences between N levels were not statistically significant although they were very clear on an average (Table 3). K percentage were lowest in the first cut of the season and highest in the third. Differences in K content were largest in the first year and diminished gradually.

Different nitrogen fertilizing treatments caused no special differences in the P content of the yield. The lowest figures were recorded in the

Table 2. Crude protein content of dry matter and protein yields in 1971—73.

Fertilizers *)	Crude protein		Nitrogen levels **)	Crude protein	
	%	kg/ha		%	kg/ha
Oulu saltpetre ...	16,9	1 446	150	13,1	914
Nitrochalk	17,6	1 444	300	16,3	1 431
Urea	16,4	1 358	450	21,4	1 902

*) **) see Table 1.

Table 3. K, P, Ca, and Mg content of herbage in different N-fertilizing treatments (% in dry matter).

Fertilizers *)					Nitrogen levels **)				
	K	P	Ca	Mg		K	P	Ca	Mg
Oulu saltpetre	3,6	0,29	0,90	0,23	150	3,4	0,30	0,82	0,19
Nitrochalk ..	3,8	0,29	1,05	0,20	300	3,6	0,29	0,93	0,21
Urea	3,6	0,30	0,92	0,20	450	3,9	0,29	1,10	0,23

*) **) } see Table 1.

first cut and they increased towards the autumn. There was quite a big difference between the years. P content was highest in the second year harvest and there were no differences between the first and third years.

Nitrochalk gave the highest Ca content in the herbage. The more nitrogen given, the higher the calcium percentage became. Significant differences were recorded between the 150—450 and 300—450 kg/ha treatments. The calcium content increased slightly with the years. In every season the Ca content was highest in the midsummer cut. There was no difference between the first and third cut. Oulu saltpetre caused the highest Mg content of the herbage. The difference between it and nitrochalk and urea was significant. The differences between the nitrogen levels were also highly significant: the more nitrogen fertilizing, the more magnesium in the herbage. The fluctuation in the Mg content was nearly identical with that of calcium. Mg content was lowest in the spring herbage and highest in the midsummer herbage.

Changes in the soil

Soil samples were taken before and after the experimental period. During this time there was a heavy decline in the K and Mg content of the soil. Different nitrogen fertilizers had the same effect on potassium content, but nitrochalk exhausted the soil magnesium more than urea or Oulu saltpetre. The difference between Oulu saltpetre and other fertilizers was highly significant. The nitrogen levels had an influence on the soil. The more nitrogen given, the more K and Mg were exhausted from the soil. Nitrochalk increased the calcium content of the soil. The other fertilizers had a low depressing effect and the difference was highly significant. There was no clear effect of treatments on the phosphorus content of the soil.

Table 4. Nutrients in soil before and after the experiment (mg/l soil).

	K	P	Ca	Mg		K	P	Ca	Mg
Starting point	270	11,2	1 750	69		270	11,2	1 750	69
After treatments with fertilizers*)	Fertilizers*)				Nitrogen levels**)				
Oulu saltpetre	117	11,2	1 617	57	150	135	11,2	1 725	54
Nitrochalk ..	117	10,7	1 883	39	300	120	11,8	1 667	50
Urea	122	12,0	1 600	47	450	100	10,8	1 717	39

*) **) } see Table 1.

Nitrogen fertilizing had a very distinct effect on the pH of the soil (Fig. 1). Nitrochalk increased and Oulu saltpetre and urea decreased the soil pH, especially with the heavier nitrogen treatments. The difference between nitrochalk and the others was highly significant. The interaction of fertilizers at different N levels was significant, too.

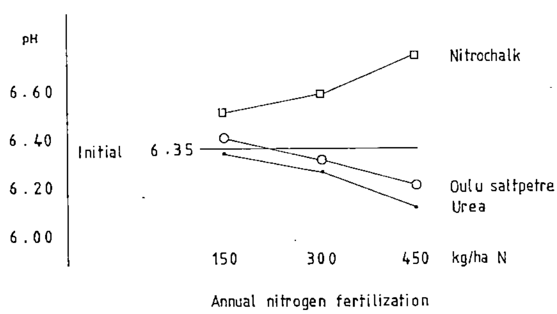

Fig. 1. Changes in soil pH effected by different nitrogen fertilizers and levels during three years of treatment.

DISCUSSION

Herbage yields in this experiment were normal in spite of the northern conditions. The drop in the third year was greater than usual due to heavy thinning of the sward and due to the severe drought. The effect of nitrogen fertilizing on the dry matter content of the herbage was as recorded elsewhere (Hiivola et al. 1974). Urea produced a little drier herbage than other fertilizers. This phenomenon was distinct with high N rates. The effect of fertilizing on herbage yield was normal, too. The highest yields are often achieved in Finland by 300 kg/ha N. Although there was no statistically significant difference between the fertilizers, the Oulu saltpetre seemed to be most effective in producing herbage. It has also been very good in other experiments under these conditions (Salonen 1958). Urea gave unexpectedly high yields. The low efficiency of the nitrochalk was mainly due to the highest N treatment, with which the sward thinned most. Nitrochalk was superior in protein production. This is probably due to the suitable calcium content of the fertilizer. High potassium content in forage is often recorded from sandy soils (Rinne et al. 1974). In this experiment, potassium was spread in three applications every year and the small doses in spring probably caused the finding that the K content of the grass did not increase as much as usual. The favourable effect of nitrochalk on the calcium content of herbage and that of Oulu saltpetre on the magnesium content of herbage were due to the contents of these elements in the respective fertilizers. The yields exhausted the K and Mg from the soil. This is a problem in intensive forage production of grasslands (Sillanpää and Rinne 1975). The decrease in the soil pH when urea or Oulu saltpetre was used indicates the need for more liming than usual. Urea is often regarded as an inefficient nitrogen fertilizer, but in this and Raave's (1962) study it was fairly good. If a comparison is made of the price of nitrogen in solid fertilizers, urea is a profitable fertilizer in forage production.

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SELOSTUS

Eri typpilannoitteiden käyttö nurminatanurmella

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Etelä-Savon koeasemalla tutkittiin vuosina 1971—73 hietamaalla oulunsalpietarin, kalkkisalpietarin ja urean vaikutusta nurminatanurmeen. Typpikoejäsenet olivat 150, 300 ja 450 kg N/ha levitettynä kolmena yhtä suurena eränä. Myös kalium levitettiin kolmena eränä vuosittain à 75 kg 60 % kalisuolaa joka sadolle. Superfosfaattia levitettiin 1971 500 ja seuraavina vuosina 300 kg/ha kerralla keväällä. Sato niitettiin v. 1971 ja 1972 kolme kertaa ja 1973 vain kaksi kertaa poudan vuoksi.

Suurin kuiva-ainesato saatiin oulunsalpietarilla, keskimäärin 8 620 kg/ha. Kalkkisalpietarilla ja urealla saatiin hieman pienemmät, keskenään jokseenkin yhtä suuret sadot. Sensijaan valkuaisen tuottajana kalkkisalpietari oli paras, urea heikoin. Lannoitelajien vaikutuksen erot sadon kivennäispitoisuuteen olivat melko pienet. Kalkkisalpietari lisäsi sadon Ca- ja oulunsalpietari Mg-pitoisuutta.

Kaikki lannoitteet tyhjensivät maan käyttökelpoiset kaliumvarat koekauden aikana noin puoleen, sitä tehokkaammin mitä suurempi oli typpilannoitus. Myös magnesium väheni maassa lievästi jopa oulunsalpietariruuduilla. Kalkkisalpietari nosti maan pH-lukua, urea ja oulunsalpietari laskivat sitä, lievästi jo 300 kg:n typpimäärällä ja selvästi suurimmalla annoksella.

Urea oli käytetyistä lannoitteista teholtaan heikoin, mutta erot olivat pienet, joten hintaansa verrattuna se osoittautui hyvin edulliseksi typpilannoitteeksi nurmille.

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Seria AGRICULTURA N. 64 — Sarja PELTOVILJELY n:o 64

COMPARISONS BETWEEN NORDIC RED CLOVER VARIETIES IN CLOVERGRASS MIXTURES

TIMO MELA, ERKKI HUOKUNA, JAAKKO KÖYLIJÄRVI, KALLE RINNE, PAAVO SIMOJOKI and PENTTI TEITTINEN

MELA, T., HUOKUNA, E., KÖYLIJÄRVI, J., RINNE, K., SIMOJOKI, P. & TEITTINEN, P. 1980. **Comparisons between Nordic red clover varieties in clovergrass mixtures.** Ann. Agric. Fenn. 19: 131—141. (Agric. Res. Centre, Inst. Plant Husb. SF—31600 Jokioinen, Finland.)

During the years 1975—1977, growing experiments were carried out on different varieties of red clover at six experimental stations in southern and Central Finland. Nordic red clover varieties were compared in clover-grass mixtures cut both twice (for hay and aftermath) and three times (for silage). The experiment was continued for a third year at three stations; in the other three, it was discontinued after two years, due to the red clover having for the most part disappeared from the grass.

The study included 13 varieties of red clover. The tetraploid varieties, Finnish Tepa and Swedish Ulva, provided the greatest yields of any of the varieties tested and were more durable than the control variety, Hankkijan Venla. The Bjursele variety from northern Sweden was exceptionally hardy. In the third year, Bjursele provided the largest average yield for silage, almost double that of the control variety. The average hay yield from Bjursele was equal to that from the control variety: Bjursele which had been cut three times, however, provided a larger harvest than the control. The regrowth of Bjursele after the first cut was less than that of the other varieties, the greater part of its total harvest having been obtained from the first cutting.

The Finnish control variety, Hankkijan Venla, provided a large crop of hay; only the tetraploid varieties and Bjursele reached the same level. However, Venla did not have the durability of the tetraploid and Bjursele varieties. Of the older Finnish varieties, Jokioinen red clover was more durable than the control variety and provided a silage yield equal to that of the control. Tammisto red clover was definitely less durable than the control, as were the Swedish Reko and Disa and Norwegian Molstad. The Finnish tetraploid line VT2 did not reach the level of the tetraploid varieties; the diploid line VD2 fell far behind the best varieties.

Index words: Red clover varieties, hay yield, silage yield, regrowth, durability.

INTRODUCTION

Recently, increased interest has again been aroused in red clover cultivation. This is primarily due to the continuous increase in the price of nitrogen fertilizers. Possibilities for cultivating red clover in Finland and its importance to Finnish farmers, are, however, decidedly limited by its poor ability to survive the winter and lack of durability in leys, as well as by occasional difficulties in cultivation for seed.

A considerable number of Finnish studies have been made on breeding red clover for durability (Valle 1958 a, 1958 b, Multamäki 1959, Paatela 1962, Ravantti 1965), better growing techniques (Teittinen 1959, Salonen and Hiivola 1963, Huokuna 1965, Raininko 1968), cultivation for seed (Valle 1936, 1960, Hänninen 1958, Paatela and Heinrichs 1959, Valle et al. 1964, 1971, Mela 1969), and improving hardiness (Virtanen and Nurmia 1936, Ylimäki 1967), and the characteristics of red clover have become well known. However, the problems of hardiness and cultivation for seed have still only partially been solved.

The purpose of the present study was to compare the characteristics of both old and new Finnish varieties of red clover, as well as to study the adaptability to Finnish growing conditions of red clover varieties most commonly cultivated in central and northern Sweden and Norway.

MATERIAL AND METHODS

The material consists of the results from six experimental stations of the Agricultural Research Centre in Finland (Table 1). All six stations are located in southern or central Finland.

Table 1. Locaties and years of the trials, type and mineral content of soil, and fertilizing of the trials.

Experimental station	Year	Soil	pH	Mineral content, mg/l of soil				Fertilizer, kg/ha		
				Ca	P	K	Mg	N	P	K
Institute of Plant Husbandry, Tikkurila (60°17′N)	1975 1976 1977	sandy clay	5,7	2 800	9,2	280	185	10 10 10	33 33 33	62 62 62
Southwestern Finland Experimental Station, Mietoinen (60°38′N)	1975 1976 1977	sandy clay	6,1	2 100	5,2	260	560	10 18 18	59 35 35	104 62 62
South Savo Experimental Station, Mikkeli (61°40′N)	1975 1976 1977	sand	6,3	1 450	8,0	130	80	0 0 10	26 26 33	75 150 62
Central Finland Experimental Station, Vatia (62°29′N)	1975 1976	silt	5,9	1 200	7,7	110	125	35 10	53 33	58 62
Satakunta Experimental Station, Peipohja (61°16′N)	1976 1977	silt	5,5	1 100	6,2	150	195	10 10	33 33	62 62
Sata-Häme Experimental Station, Mouhijärvi (61°31′N)	1976 1977	silt	5,8	1 400	11,4	200	95	0 0	33 33	62 62

The clover trials were sown in the years 1974 and 1975. The seed mixtures used for sowing contained red clover, meadow fescue (cv. Tammisto), and timothy (cv. Tammisto) seed in a ratio of 15 (tetraploid 17) : 5 : 10, respectively. The amount used varied according to growing conditions between 20 and 30 kg/ha. Seed was all from the same stock.

Fertilizing was with 500 kg/ha of compound fertilizer (10-9-17) including boron at the spring sowing, and annual fertilization of 500 kg/ha PK fertilizer (2-8-12). At some experimental stations the fertilizing programme varied slightly.

The trials were carried out according to the split plot method with 3 replicates. The number of cuttings varied at the main plots (A) the two variations being a_1 (= 2 cuttings) and a_2 (= 3 cuttings). The variety of red clover varied at the sub plots (B); altogether 11—13 different varieties were used (b_1-b_{13}). In the Sata-Häme and Satakunta Experimental Stations, only trials to be cut twice were established. The sub-plot varied in size from 10 to 15 m^2 depending on the experimental station.

The main plots that were to be harvested twice were cut for the first time at the hay stage when the clover had already begun to blossom and the hay racemes had emerged completely from the leaf sheath. The second harvest was carried out at the end of August or beginning of September. The main plots that were to be harvested three times were cut at the silage stage; firstly when the hay racemes were just beginning to emerge from the sheath, secondly about one month after the first cutting, and thirdly at the same cutting as the main plots cut twice (i.e. at the end of August or beginning of September).

The average cutting dates at the different localities were for the leys harvested twice July 9 and September 4, and for the leys harvested three times June 19, July 31 and September 4.

The forage yields of the cuts were weighed by plot. Before the botanical analysis, samples from each of the replicates were combined. In additions, the dry-matter content of the yield was determined.

The results were analyzed with the paired t-test. Table 1 shows the results of the soil fertility analyses from the experimental fields. The fertility corresponds to the normal levels for Finnish fields. However, some of the pH values were rather low for the cultivation of red clover.

The following red clover varieties were compared in the experiment:

Hankkijan Venla (2n) Hankkija Plant Breeding Institute, Finland. Control variety from 1978.

Tammisto (2n) Hankkija Plant Breeding Institute, Finland. Previous standard variety. Old variety from 1937.

Jokioinen red clover (2n) Agricultural Research Centre, Plant Breeding Institute, Finland. Old variety from 1961.

Tepa (4n) Agricultural Research Centre, Plant Breeding Institute, Finland. The only Finnish tetraploid red clover variety. Released for sale in 1964.

Disa (2n) Svalöf Plant Breeding Institute, Sweden.

Reko (2n) Svalöf Plant Breeding Institute, Sweden.

Bjursele (2n) Local variety from northern Sweden.

Ulva (4n) Svalöf Plant Breeding Institute, Sweden.

Molstad (2n) Common variety in Norway.

Opdal El (2n) Local variety from northern Norway.

VD2 (2n) University of Helsinki, Department of Plant Husbandry, Finland. Breeding line.

VT2 (4n) University of Helsinki, Department of Plant Husbandry, Finland. Breeding line.

Sv Å 0125 (4n) Svalöf Plant Breeding Institute, Sweden. Breeding line.

Clover yields from the leys for hay

The largest **hay yields** were produced by the tetraploid varieties, Tepa and Ulva (Table 2). However the difference in their yields of 4—5 % in comparison with the control variety (Hankkijan Venla) was not statistically significant. Bjursele, VT2, and Jokioinen red clover produced hay yields as high as the control variety; the yield of Molstad did not differ significantly from that of the control, either. The difference of 11 % between the yields of VD2 and Venla was statistically significant, as were the differences of 16, 18 and 22 % between the yields of the varieties Tammisto, Reko and Disa, respectively, as compared to Venla.

Large differences in **aftermath** yields illustrate the great variation in the regrowth capacity of red clover varieties. Regrowth of Ulva and Tepa was greater than that of Venla, the difference between Ulva and Venla being statistically significant. The regrowth of Bjursele was 36 % smaller, Molstad 21 %, VD2 23 %, Jokioinen red clover 20 %, Disa 13 %, and Tammisto red clover 11 % smaller than that of the control variety. The 13 % difference between Reko and Venla was not statistically significant; the regrowth of VT2 and Venla was equal.

In terms of the **total yield,** only the Tepa and Ulva varieties were better, by 6—8 %, than Venla. Their superiority was not statistically significant. The total yields of Tammisto, Disa and Molstad were 14, 18 and 13 % smaller, respectively, than that of Venla. The differences were statistically significant. Differences in the average yields of Jokioinen red clover (10 %), Bjursele (14 %), VD2 (16 %) and Reko (16 %) were not significant when compared with Venla's yield.

Table 2 also shows the calculated proportion of the aftermath in the total yield, which to some extent reflects the growth pattern of a

Table 2. Average dry-matter yields of red clover varieties (red clover kg/ha).

	Venla	Tammisto	Jokioinen	Tepa	Bjursele	Disa	Reko	Ulva	Molstad	VD2	VT2
2 cuttings											
(results from 16 samples)											
Hay yield, kg/ha	3 150	2 650*	3 040	3 300	3 170	2 480**	2 590*	3 330	2 910	2 820°	3 110
Ratio	100	84	96	104	100	78	82	105	92	89	98
Aftermath, kg/ha	2 020	1 810°	1 620*	2 190	1 300**	1 760°	1 770	2 260*	1 610**	1 560*	2 050
Ratio	100	89	80	109	64	87	87	111	79	77	101
Total clover yields, kg/ha	5 170	4 460**	4 660	5 490	4 470	4 240*	4 360	5 590	4 520*	4 380	5 160
Ratio	100	86	90	106	86	82	84	108	87	84	100
% of aftermath in total yield	39	41	35	40	29	42	41	40	36	36	40
3 cuttings											
(results from 11 samples)											
% of total yield											
Spring cut	32	32	34	34	43	33	35	29	33	38	35
Summer cut	42	42	40	39	35	41	38	44	40	36	39
Autumn cut	26	26	26	27	22	26	27	27	27	26	26
Total clover yield, kg/ha	2 880	2 750	3 100	3 800**	3 450*	2 650	2 670	3 640**	2 830	2 640	3 250
Ratio	100	95	107	131	119	92	92	126	98	91	112
% of twice cut (calculated from same 11 experiments)	64	70	68	73	77	72	64	72	74	65	69

** = Significance P = 99,0 %
* = » P = 99,0 %
° = » P = 90,0 %

variety. The proportion of the second crop was about 40 % of the total yield in most varieties (range 39—42 %).

The aftermath of Bjursele was, however, clearly less than that of the other varieties, being only 29 % of the total crop. The proportion of the aftermath in the total yield appeared to be slightly less in the case of Jokioinen red clover, Molstad, and VD2 than that in the case of Venla.

Clover yields of the leys for silage

The tetraploid varieties produced the best clover yields in leys cut three times at the silage stage (Table 2). The total clover yield from Tepa was 31 % and from Ulva 26 % greater than from Venla, both differences being statistically significant. A significantly greater yield of 19 % was also produced by Bjursele in comparison with Venla; differences of 7 % for Jokioinen red clover and 12 % for VT2 were not statistically significant. Tammisto red clover, Disa, Reko, Molstad, and VD2 produced yields an average of 5—9 % smaller than the yield from Venla, but the differences were not statistically significant.

The average proportion of the spring crop was 35 %, summer crop 39 %, and autumn crop 26 % in the total clover yield of the leys for silage. Most varieties varied slightly in this respect. However, the percentage of the spring yield of Bjursele was higher than that of the other varieties.

Clover that was cut three times produced an average dry matter yield that was 70 % of that of the dry matter yield of twice cut clover (Table 2). Bjursele gave the highest percentage, 77. The smallest ratios were those from Venla and Reko, both being 64 %.

Variation in the clover yields

The clover yields varied greatly according to the trial localities and years depending on the different growth conditions and the density of the stand. The coefficients of variation (%) for the yields for hay (late cut for hay) and for silage (total of the cuts per season) of the red clover varieties are as follows:

	Hankkijan Venla	Tammisto	Jokioinen	Tepa	Bjursele	Disa	Reko	Ulva	Molstad	VD2	VT2
Hay yield	54	54	66	50	72	65	56	53	59	60	58
Silage yield	69	70	70	48	67	67	63	46	72	74	70

The yields of the tetraploid varieties Tepa and Ulva varied less than the other varieties, especially in the leys for silage. Compared with the other varieties, the hay yields of Jokioinen and Bjursele varied more, but the variation of the yields of these two varieties for silage were similar.

Durability of red clover varieties in grass mixtures

Under Finnish conditions, one of the most important properties of a red clover variety is its durability and permanence in ley. In choosing a red clover variety for cultivation, more attention is paid to its wintering characteristics and permanence than to any large yields it may produce under good growing conditions.

Figure 1 shows the differences in yields of red clover varieties in grass mixtures of varying age, which also shows the permanence of the clover during the two or three years of these experimental trials. The relative hay and silage yields of most varieties increased in comparison with that of Venla as the age of the grass mixture

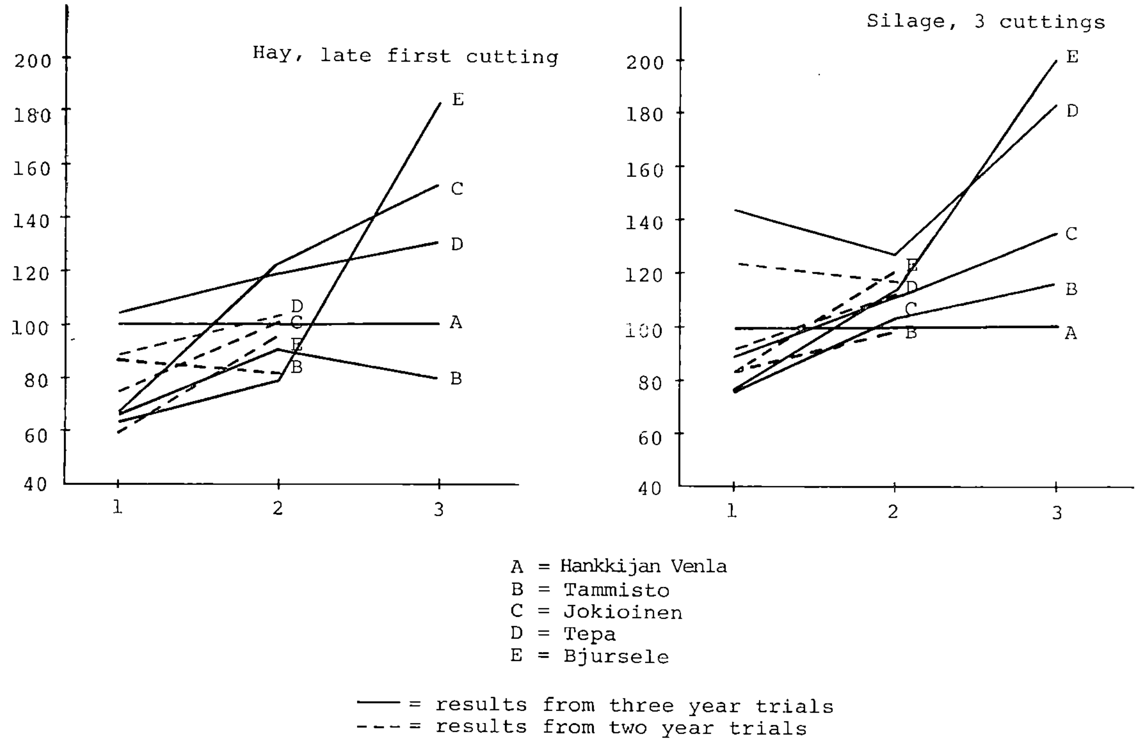

Fig. 1. Relative yields of some red clover varieties in leys of different ages. (Hankkijan Venla = 100.)

increased. Bjursele had the best durability among the varieties; its yield ratio increased from about 70 in the first year to nearly 200 in the third year. A similar trend was observed in the ratios of Tepa and Jokioinen red clover, which were also more permanent in the grass mixture than was Venla. However, Tepa gave yields that were higher than those of Venla even in the first year, particularly when cut three times a year. In the third year, Tepa's hay yields were 31 % and its silage yields 83 % larger than the respective yields for Venla. The respective percentages for Jokioinen red clover were 53 and 36 %.

Hay yields from Tammisto red clover were smaller than from Venla in grass mixtures of all ages. However, third year yields from grass mixtures cut three times were on average larger than those from the control variety.

Clover percentage

The average red clover content of the hay yields was higher than that of the spring yields from leys for silage which were harvested at an earlier stage of development (Table 3). This is due to the fact that the growth of red clover in the spring is at first slower than the growth of grasses, becoming more rapid as the temperature increases in June.

The yield of the second crop from leys for both hay and silage was made up of an average of two-thirds red clover and one-third grasses. Thus, red clover was important in the second crop. It should, however, be noted that the entire clover yield in leys for silage was only two-thirds that of the clover yield in leys for hay and aftermath, the clover yield in hay being double that of the yield in silage at the first cutting (Table 2).

Table 3. Percentage of red clover in the total yield of clover-grass mixtures at different age of ley and at different cuttings.

Variety	Number of cut	Age of ley, years			Cutting		
		1	2	3	A	B	C
Venla	2 (hay & afterm.)	66	68	39	42		66
	3 (silage)	63	59	37	32	61	68
Tammisto	2	64	66	32**	44*		63
	3	63	62	39	33	61	69
Jokioinen	2	59**	69	49**	53		65
	3	50*	57	45**	34	54	64
Tepa	2	66	72	49*	52		73°
	3	69°	66°	61***	41*	74**	82*
Bjursele	2	50***	59**	58*	53		59**
	3	60	58	59*	47*	64	66
Disa	2	63°	64	33	42*		65
	3	69	58	38	40	60	66
Reko	2	64	65	37	44°		67
	3	67	56	40	35	61	67
Ulva	2	66	72	50*	52		72*
	3	65	65*	57***	39°	70**	79*
Molstad	2	59*	64	38	46		60*
	3	60	59	42	32	59	71
(Opdal El)	2	21	57	47	47		52
	3	26	54	51	23	49	59
VD2	2	63	65	41	50		64
	3	61	60	46	39°	63	64
VT2	2	64	68	51*	52		68
	3	65	66*	50*	40*	70*	71
Sv Å 0125	2	48°	61°	40	43°		76**
	3	48	59	63**	30	75**	65*
Average	2	59	65	46	48	65	65
	3	59	61	50	39	63	69

*** = Significance P = 99,9 %
** = » P = 99,0 %
* = » P = 95,0 %
° = » P = 90,0 %

A = spring
B = summer
C = autumn

The proportion of most red clover varieties in the hay yield was similar to the proportion of Venla. In the hay yield, no variety gave a red clover content which was statistically significantly higher than Venla. The red clover contents of the Tammisto, Disa, Reko, and Sv Å 0125 leys were significantly lower than that of Venla. Significantly higher red clover contents were found in the second crops of Tepa, Ulva, and Sv Å 0125 as compared to the control variety. On the basis of red clover percentages, Bjursele and Molstad were poorer in terms of regrowth in comparison with Venla.

The tetraploid varieties Tepa, Ulva, and VT2 produced higher clover contents than Venla in leys for silage; in the spring yield, Bjursele also produced a significantly higher clover content than Venla.

The red clover contents of leys for hay and leys for silage are not comparable among leys of varying ages (Table 3), as the difference in the stage of growth at the harvest influences the clover content, as does the different number of spring and second harvests.

The tetraploid varieties Tepa, Ulva, VT2 and Sv Å 0125 (the latter only in leys for silage) appeared to have greater durability than Venla, as did Jokioinen red clover and Bjursele. In the first year leys for hay, the clover contents of Jokioinen red clover, Bjursele, Disa, Molstad, and Sv Å 0125 were lower than the clover content of Venla.

DISCUSSION

The competition between red clover and the grasses obviously had a certain influence on the results presented above. It is conceivable that the competition increased the differences between varieties in comparison with differences that might arisen in variety trials of red clover alone, because faststarting, vigorous varieties would do better in competition with grasses than would slower growing red clover varieties. When experimental leys were not fertilized with nitrogen (except for some minor amounts of nitrogen which may have been in the PK fertilizer used), the competition from grasses was relatively weak.

If the leys had been fertilized with nitrogen, the proportion of grasses in the yields would have increased together with the nitrogen fertilizing. In clover grass mixtures, it is primarily the grass that benefits from nitrogen fertilizing; such fertilizing can even be harmful to the clover. This has been demonstrated by SALONEN and HIIVOLA (1963), among others.

According to the results presented above, the superiority of the tetraploid varieties of red clover is convincing when compared with the diploids, although the hay yields did not deviate enough from those of Venla to be statistically significant, as Venla is also a good producer of hay. The superiority of Tepa and Ulva in comparison with the control variety became even more apparent in the leys for silage and when the ley aged.

The good durability and yield of the tetraploid varieties were well known even before the present study. According to VALLE (1968), the better yield of tetraploid red clover varieties in comparison with diploids is based on their luxuriant growing habits and their better resistance to clover root rot.

The standard variety, **Hankkijan Venla,** proved to be a variety which produced good yields, particularly when cut for hay. It did not give as favourable an impression in leys for silage; several varieties produced equal or even greater yields. Tepa, Ulva, and Bjursele all produced yields for silage that were clearly significantly larger than the yield from Venla. Venla did not have the same durability as the three varieties mentioned above; in this respect Venla also falls behind the tetraploid varieties VT2 and Sv Å 0125, and Jokioinen red clover. However, when its large hay yields and ease of seed production are taken into consideration, Venla proves to be a good, general variety on the basis of these trials, as well.

Bjursele is a variety typical of northern growing conditions. It is early, blooming more than a week before Venla, and its regrowth is less than that of the other varieties in the trials. This variety grows in dense, but low, stands, and small leaves. In rainy summers, Bjursele's regrowth appears to be greater than usual; in this respect the trial year 1977 was clearly favourable for Bjursele. It is possible that

Bjursele's yield formation suffered to some extent in the case of the leys cut for hay since Bjursele reaches the blooming stage earlier than the others. As the trial plots were cut only when all varieties had begun to bloom, Bjursele had to wait for the cutting, although it no longer grew as much as later varieties. At the same time, the period between cuttings became shorter. This may explain to some extent Bjursele's relatively poor total yield in leys for hay as compared with the results of leys for silage. As Bjursele is very durable, its relative yield rating improves with the age of the ley. Since poor durability is one of the greatest problems in the cultivation of red clover under Finnish conditions, Bjursele appears to be very promising. It is hoped that it can be adapted for cultivation even under the difficult winter conditions of eastern and northern Finland.

Jokioinen red clover proved to be a very hardy variety in these trials. It produced yields comparable to Venla's. The regrowth did not, however, reach the level of the control variety. Another old variety, **Tammisto red clover,** clearly fell behind Venla in both size of yield and hardiness.

Disa, Reko, and **Molstad,** the varieties most commonly cultivated in Sweden and Norway, were unable to produce better average yields under Finnish conditions than the best varieties included in the trials.

According to the results from Swedish trials (Andersson 1975), Disa and Reko, in addition to Bjursele, have done better than other local varieties under conditions in northern Sweden (in a region which is further north than any of the trial locations presented in this study). In central Sweden, where the number of different varieties is greater than in the North, the relative success of Disa and Reko was poorer (Simon 1977). Also in the Swedish trials, Reko gave better yields than Disa. Bjursele does not appear in the results of variety trials conducted in central Sweden.

The tetraploid line **VT2** gave yields which were smaller than those of Tepa and Ulva. The Swedish tetraploid line **Sv Å 0125** appears to be promising in the light of the results obtained in two trials. The local variety from northern Norway, **Opdal El,** produced only small yields in the only trial in which it was included.

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SELOSTUS

Pohjoismaisten puna-apilalajikkeiden vertailua apila—heinänurmessa.

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Maatalouden tutkimuskeskus

Vuosien 1975—1978 aikana suoritettiin kuudella Etelä- ja Keski-Suomessa sijaitsevalla koepaikalla puna-apilan lajikekoe, jossa verrattiin pohjoismaisia puna-apilalajikkeita sekä kahteen (heinänurmi) että kolmeen (säilörehunurmi) kertaan niitetyssä apila-heinä seosnurmessa. Kolmella koepaikalla koe jatkui kolmen vuoden ajan, kolmella muulla se jouduttiin keskeyttämään kahden vuoden jälkeen apilan pääosaltaan hävittyä nurmesta.

Kaikkiaan kokeessa oli 13 puna-apilalajiketta. Tetraploidit lajikkeet suomalainen **Tepa** ja ruotsalainen **Ulva** olivat lajikkeista satoisimpia ja mittarilajiketta **Hankkijan Venlaa** kestävämpiä. Myös tetraploidi ruotsalainen linja **Sv Å 0125** oli satoisa ja kestävä niissä kokeissa, joissa se oli mukana. Erityisen kestäväksi osoittautui pohjoisruotsalainen **Bjursele,** joka kolmantena koevuotena antoi keskimäärin suurimpia rehusatoja, lähes kaksinkertaisia mittarilajikkeeseen verrattuna. Bjurselen keskimääräinen heinäsato oli mittarin tasoa, kolmeen kertaan niitettyjen nurmien sato suurempi kuin mittarin. Bjurselen odelman kasvu oli vähäisempää kuin muiden lajikkeiden ja suurempi osa kokonaissadosta saatiin ensimmäisellä niittokerralla.

Kotimainen mittarilajike Hankkijan Venla tuotti suuria heinäsatoja, vain tetraploidit lajikkeet ja Bjursele yltivät sen kanssa samalle tasolle. Kestävyydeltään tämä lajike ei ollut tetraploidien ja Bjurselen veroinen. Vanhoista suomalaisista lajikkeista **Jokioisten puna-apila** osoittautui mittaria kestävämmäksi ja säilörehunurmilla satoisuudeltaan mittarin veroiseksi, **Tammiston puna-apila** jäi selvästi mittaria heikommaksi. Ruotsalainen **Reko** ja norjalainen **Molstad** olivat mittaria satoisampia vain kasvuoloiltaan kaikkein edullisimmalla koepaikalla, ruotsalainen **Disa** tällöinkin vain säilörehunurmissa. Näiden lajikkeiden heikkous oli huono kestävyys. Kotimainen tetraploidi linja **VT 2** ei yltänyt tetraploidien lajikkeiden tasolle, diploidi linja **VD 2** jäi parhaista lajikkeista selvästi jälkeen. Norjalainen paikallislajike **Opdal El** oli vain yhdessä kokeessa mukana.

ANNALES AGRICULTURAE FENNIAE, VOL. 19: 142—155 (1980)

Seria AGRICULTURA N. 65 — Sarja PELTOVILJELY n:o 65

WINTER HARDINESS AND YIELD OF LOCAL VARIETIES OF FINNISH RED CLOVER GROWN IN SOUTHERN FINLAND AT THE ANTTILA EXPERIMENTAL FARM OF THE HANKKIJA PLANT BREEDING INSTITUTE IN 1962—1966.

SAIJA RAVANTTI

RAVANTTI, S. 1980. **Winter hardiness and yield of local varieties of Finnish red clover grown in southern Finland at the Anttila Experimental Farm of the Hankkija Plant Breeding Institute in 1962—1966.** Ann. Agric. Fenn. 19: 142—155. (Agric. Res. Centre, Inst. Plant. Breed. SF—31600 Jokioinen, Finland.)

The cultivation of red clover in Finland declined in the 1960s, while that of heavily nitrogen fertilized hay grasses became more common. At the beginning of the 1980s, with re-expansion of red clover cultivation under consideration, presentation of the main features of the author's previously unpublished study on the cultivation value of commercial seed lots of domestic red clover carried out at the Anttila Experimental Farm of the Hankkija Plant Breeding Institute in 1962—1966 has become worthwhile. The results provide background information on the question of whether expanded cultivation of red clover should be based solely on domestic commercial varieties, or whether the cultivation of good, naturally occurring, local varieties should also be promoted.

The cultivation values of 390 local varieties of Finnish red clover, which were supplied in 1960 and 1961 and approved for the official seed trade as forage were compared with the values for Tammisto red clover, the control variety in the trial, and those for Altaswede, the main variety imported between 1940 and 1962. Local varieties came from the operational areas of 15 agricultural societies.

Tammisto red clover developed slower during the summer immediately following the sowing, but had better winter durability in the 2nd and 3rd year leys. It produced a better yield in the second year and particularly in the third year; it was a later variety with fewer flower heads than the majority of the local varieties. Altaswede developed faster during the summer following the sowing, had a poor winter hardiness value in the 2nd and 3rd year leys, and yielded less in the second and particularly the third year leys than did Tammisto or a large number of the local varieties. In the third year ley, two local variety trial materials had a winter hardiness value 8,0 % and 14,1 % better than that of Tammisto red clover, but were less hardy than Altaswede by 76,0 % and 31,6 %, respectively. They yielded 11,1 % and 9,3 % more than Tammisto red clover, and 45,2 % and 44,3 % less than Altaswede, respectively. A number of local varieties with higher yields and better winter hardiness than Tammisto red clover were found among the local varieties of each agricultural society. The study demonstrated that in the early 1960s many valuable local varieties were being cultivated as forage in different parts of Finland. If they are still being cultivated on a small scale, the expansion of their cultivation should be considered.

Index words: Red clover, local variety, Tammisto red clover, Altaswede red clover, winter hardiness, yield, leafiness, earliness, frequency of flower heads.

Certain characteristics of red clover, such as its ability to fix nitrogen, good yields, and value as forage and as preceding crop, have been highly appreciated in Finland since the beginning of the 20th century. Despite the efforts of agricultural extension agencies in this respect, red clover did not do well in grass leys. The main reasons for this have been determined as being due to the meagre supply of domestic red clover seed with high germination values, the poor hardiness of imported foreign seed, and unsuitable cultivation techniques (Valle 1947, 1957, 1958, 1964, Paatela 1953 a—c, 1954, Kamppinen and Schildt 1965, Mukula et al. 1967 a, b, Raatikainen, M. and Raatikainen, T. 1975).

Domestic, local varieties of red clover and improved varieties which were bred from them were highly appreciated. The production of seed from them was promoted through the use of price guarantees. Red clover seed production was, however, very risky due to climatic conditions, and was usually of insufficient volume. As a result, it was necessary to import foreign seed on a fairly regular basis (Table 1). The rapid expansion of the heavy use of nitrogen fertilizers in the cultivation of hay grasses reduced the need for red clover seed in the 1960s and even more in the 1970s. The reduction in imports of foreign seed was further influenced in the 1970s by the increased domestic production of commercial seed thanks to favourable weather. Red clover seed was imported from Canada, Estonia, Norway, the Soviet Union, and Sweden. The red clover cultivated in Finland was thus constantly subject to natural selection. New cross-breeds were continally arising between imported varieties, domestic varieties, and the local varieties (Anon. 1956, Paatela 1959, Kamppinen and Schildt 1965).

According to Kitunen's assessment (1965), 13 to 15 %, and according to Paatela (1959), 10 %, of the red clover seed sown annually

Table 1. Red clover seed imports into Finland between 1919 and 1979.

Importation period	Imports (tons)			Numbers of years with no imports
	total imports	imports/year	variation between years	
1919—1949	1 193,3	39,8	0,5—202,5	9
1949/50—1958/59 ..	2 010,4	201,0	44,9—374,0	1
1959/60—1968/69 ..	956,1	95,6	2,7—302,9	0
1969/70—1978/79 ..	132,4	13,2	10,8—100,6	7

went through the official seed trade. No data is available on the present status. Many of those who cultivated the old local strains produced seed only for themselves and their neighbours (e.g., Simola 1924, Jääskeläinen 1930, Saloheimo 1939, Multamäki 1949, Isotalo 1959, Ravantti 1961, 1965). For this reason, the seed of local varieties used in the comparative trials was acquired from farmers and not from the official seed trade, although, according to Paatela (1959), the seed of several un-named lots of Finnish red clover was offered as local varieties in the official trade. The characteristics of Finnish red clover for seed for the official seed trade were evidently well known, but not its value as a forage plant.

At the beginning of the 1980s, a revival of red clover cultivation is being considered. In this context, we must decide whether expanded cultivation of red clover should be based solely upon domestic commercial varieties, or whether the cultivation of good, still existant, local varieties should also be promoted. Some background information to this question can be obtained from a previously unpublished licenciate thesis (Ravantti 1973); it has therefore been thought worthwhile to publish the main results of this study. The study examined the cultivation value as forage of 390 Finnish red clover local varieties in trials conducted in 1962—1966 at the Anttila Experimental Farm of the Hankkija Plant Breeding Institute.

The study concentrated on the following three main questions:

1. What was the winter durability of the trial material compared with Tammisto red clover, the official control variety, and compared with Altaswede, the main imported variety in 1940—1962?

2. How do the yields of the trial material compare with those of Tammisto and Altaswede?

3. What were the average differences between varieties from different agricultural societies and between local varieties within the same agricultural society?

MATERIAL AND METHODS

The study population was composed of 390 seed lots which fulfilled the official seed trade requirements, labelled according to the cultivator's name and which were provided from rechecked samples of seed from inspection years 1960—61 and 1961—62 by the State Seed Testing Station. These seed lots were divided into four different materials. Because the Finnish red clover in the official seed trade was, according to PAATELA (1959), primarily composed of various local strains, commercial seed lots of red clover will be referred to as »local varieties» in this study. Trials were conducted in 1962—1966 at the Anttila Experimental Farm of the Hankkija Plant Breeding Institute.

The partial results from materials 1—3 are presented here (Table 2). The soil type of the trials was muddy loam clay. Basic fertilization was 700, 40 and 55 kg/ha Ca, P and K, respectively, and annual fertilization was 33 and 42 kg/ha P and K, respectively. The seed rate of red clover was 16 kg/ha.

Material 1 was established without a nurse crop, and the 1962 cutting trials were carried out with a nurse crop. In 1963, cutting trials of the third replicate were also planned, but the nurse crop was flattened causing the seedling stage to be so uneven that the trials were ploughed under. In the observation plots established in 1963, the seedlings grew evenly throughout the plot; their yield was also checked by cutting. These results were, of course, not as reliable as in the replicate trials.

The speed of initial development was observed in material 1 by measuring the average heights of the plants at regular intervals and by determining the growth habit in the autumn according to the BIRD (1948) scale, modified by VALLE and GARRISON (1959).

The winter hardiness of material 2 and 3 was determined with the following formula:

$$\text{Winter hardiness} = 100 \times \frac{\text{density (0—100) in spring}}{\text{density (0—100) in autumn}}$$

Table 2. Data on the plan of the experiment.

Number of material	Experiment	Date of sowing	Treatments (No.)	Replicates (No.)	Plot size (m^2)	Period of experiment
1	Observation plots	16. 5. 1962	394	1	2,4	1962
	Observation plots I—IV ..	17. 5. 1963	369	1	4,9	1963
2	Cutting experiments	16.—18. 5. 1962	406	3	4,9	1962—1965
3	Observation plots I—IV ..	17. 5. 1963	369	1	4,9	1963—1966

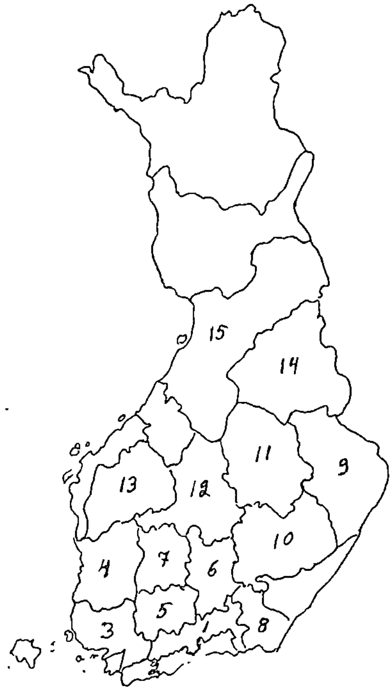
In 1963, material 1 was used in the control plots for the summer sowing; otherwise material 3 was used.

Fig. 1.

Finnish Agricultural societies

The agricultural societies from which commercial red clover seed lots were obtained are numbered as follows:

No		Number of lots
1.	Province of Uusimaa	39
2.	Swedish Agricultural Society of Nyland	54
3.	Varsinais-Suomi	8
4.	Satakunta	7
5.	Province of Häme	22
6.	East Häme	21
7.	Häme-Satakunta	16
8.	Kymenlaakso	44
9.	North Carelia	6
10.	Province of Mikkeli	74
11.	Kuopio	33
12.	Central Finland	18
13.	South Pohjanmaa	4
14.	Kajaani	5
15.	Province of Oulu	39



Every effort was made to cut the grass in the treatments at the same stage of development, twice each summer. The raw protein content was determined according to KJELDAHL's micromethod. The flowering stage was defined visually on a scale from 0 to 100. Flowering head values (flowers + buds) were counted with a frame of 1/4 of a square metre, the result being given per square metre.

Leaves, stems, and buds were determined as a percentage of weight from a 250 g air-dried sample cut with a sickle from the first year growth of material 3.

Efforts were made to separate local varieties from Altaswede crosses and pure-bred Altaswede by determining the colour of the leaves and flowers of the plants according to KORNERUP's and WANSCHER's (1961) colour tables.

Data was processed according to the agricultural society classification. Averages, deviations, variant analyses, frequency distributions, and correlation matrixes were computed in the University of Helsinki Computer Centre with the HYLPS system. The statistical significance of the results are expressed with the symbols commonly in use. Due to the abundance of the data, only partial results are presented here. Complete results may be found in the duplicated report of the study (RAVANTTI 1973).

The material was obtained from the operational areas of 15 agricultural societies (Fig. 1). According to VALLE's investigations (1964), 85 % of the commercial red clover seed was produced in southwestern Finland and in the province of Uusimaa. In this study, 24,8 % of the samples came from this area, but the majority (75,2 %) came from the inland deficit production areas where there was a strong interest in the cultivation of red clover for seed. Yields per hectare were high in this area, but the total land area actually under cultivation was small (PAATELA 1959, RAJALA 1960, HÄNNINEN 1962, 1965, KAMPPINEN and SCHILDT 1965).

Climatic conditions were not favourable during the trial period. In the late winter-early spring of 1964, there was ice and water damage in the red clover growths. In the winter of 1964—65 and 1965—66, conditions were favourable for the spread of red clover rot. The growing season of 1962 was chilly. The growing seasons of 1963, 1964, and 1966 were, on the whole, dry, and June of 1965 was particularly dry.

The following abbreviations will be used in presentation of the results: ags = agricultural society, and the names of the agricultural societies are numbered as shown in Fig. 1.

RESULTS AND DISCUSSION

Speed of development during the summer succeeding the sowing

The growth of material 1 was disturbed by damp, chilly weather in the summer of 1962 and by drought in the summer 1963. The majority of the local varieties developed slower than Altaswede but faster than Tammisto clover on the basis of measurements of the growth height, growth habit, and number of flowering heads. The properties under investigation were very significantly dependent on each other. The varieties with the most rapid development were the local varieties of southern agricultural societies 1—5, 7, and 9; the slowest were the local varieties of northern agricultural societies 10—15. The slow development of northern varieties has also been demonstrated even when

Table 3. Winter hardiness of local varieties in material 2.
Ka = Mean Ha = Standard deviation

	Winter hardiness 0—100 %								
	1962—64	1962—63		1963—64		1964—65			1962—65
	Lots (No.)	Ka	± Ha	Ka	± Ha	Lots (No.)	Ka	± Ha	Ka
Tammisto	4	90	±2,9	65	±32,1	2	72	±12,4	76
Altaswede	4	86	±8,0	57	±30,5	2	69	±14,2	71
Agricultural societies									
1. Province of Uusimaa	39	93	±3,5	58	±19,5	32	37	±19,0	63
2. Swedish Agricultural Society of Uusimaa	54	92	±4,6	65	±21,2	49	44	±26,7	67
3. Varsinais-Suomi	8	95	±1,5	58	±20,0	7	35	±22,9	63
4. Satakunta	7	92	±2,9	67	±23,6	7	41	±22,5	67
5. Province of Häme	22	93	±3,4	63	±21,8	19	41	±24,4	66
6. East Häme	21	93	±3,9	67	±24,6	21	49	±25,3	70
7. Häme-Satakunta	16	93	±2,7	62	±22,2	15	33	±21,1	63
8. Kymenlaakso	44	95	±2,3	71	±14,4	40	36	±18,4	67
9. North Carelia	6	95	±3,2	76	±11,7	6	50	±17,7	74
10. Province of Mikkeli	75	95	±3,2	75	±16,9	72	49	±22,3	73
11. Kuopio	32	95	±2,9	72	±15,3	29	48	±18,9	72
12. Central Finland	18	95	±2,5	86	± 7,6	18	62	±10,4	81
13. South Pohjanmaa	4	95	±2,6	94	± 3,8	4	66	± 7,4	85
14. Kajaani	5	96	±1,1	87	± 6,9	5	47	±13,5	77
15. Province of Oulu	39	95	±1,6	86	±11,4	39	57	±13,1	79
Ka 1—15		94		72			46		71

Table 4. Winter hardiness of local varieties in material 3.
Ka = Mean Ha = Standard deviation

	Lots (No.)	Winter hardiness 0—100 % 1963—64 Ka	1963—64 ± Ha	1964—65 Ka	1964—65 ± Ha	1965—66 Ka	1965—66 ± Ha	1963—65 Ka
Tammisto	4	89	±5,3	94	± 0,5	30	±14,2	71
Altaswede	4	88	±5,1	93	± 3,1	16	± 2,5	66
Agricultural societies								
1. Province of Uusimaa	38	93	±4,9	87	± 7,9	18	± 9,0	66
2. Swedish Agricultural Society of Uusimaa	42	90	±6,4	86	± 9,7	21	±12,0	66
3. Varsinais-Suomi	5	93	±7,6	90	± 3,8	16	± 6,3	66
4. Satakunta	5	93	±7,6	92	± 2,7	16	±12,8	67
5. Province of Häme	19	87	±2,1	82	± 2,1	21	±12,8	63
6. East Häme	19	93	±5,8	88	± 8,1	20	± 8,1	67
7. Häme-Satakunta	15	95	±4,4	81	±17,6	24	±10,5	67
8. Kymenlaakso	42	92	±5,2	89	± 9,1	20	±10,7	67
9. North Carelia	6	92	±7,2	89	± 8,2	18	±13,3	66
10. Province of Mikkeli	65	90	±7,1	89	± 7,4	25	±12,7	68
11. Kuopio	32	87	±8,6	93	± 3,0	25	±13,1	68
12. Central Finland	15	86	±7,1	92	± 5,4	17	±11,2	65
13. South Pohjanmaa	3	88	±7,6	94	± 0,6	18	±11,6	67
14. Kajaani	3	83	±2,9	94	± 0,0	36	±12,3	71
15. Province of Oulu	37	89	±7,1	91	± 4,4	22	±11,9	67
Ka 1—15		90		89		21		67

cultivating them further south by UMAREUS (1963) and VALLE and GARRISON (1959). On the other hand, there were both slow developers and fast developers among the local varieties from all the agricultural societies. The correlations between the degree of latitude of the home location of the local varieties and the variables of material 1 were negative and statistically highly significant.

Winter hardiness

Deterioration in winter hardiness as the ley aged was typical of local varieties, except in the case of the second year ley of local varieties in agricultural societies 11—15 of material 3, which had good winter hardiness (Tables 3 and 4). The cold, the ice cover, frost damage, and clover rot were the most important causes of winter damage. The winter hardiness of Tammisto red clover was better than that of Altaswede, particularly in the third winter. The proportion of local varieties that wintered as well as or better than Tammisto declined in all the materials as the leys aged. After the third winter, 8,0 % of the local varieties in material 2 and 14,1 % in material 3 were classified as being better than Tammisto as far as their winter hardiness value was concerned. In material 2, 71,0 % of the local varieties were inferior to Altaswede in winter hardiness, as were 31,1 % of the local varieties in material 3 (Fig. 2).

In material 2, the local varieties of agricultural societies 13, 12, 15, and 14, and in material 3 those of societies 14, 10, and 11, wintered best on average during the three winters. Among the local varieties from each of the agricultural societies there were always some that had a winter hardiness value at the same level as or better than that of Tammisto red clover.

The correlation between the winter hardiness and the latitude of a local variety's place of origin was, in material 2, for the 1st to 3rd

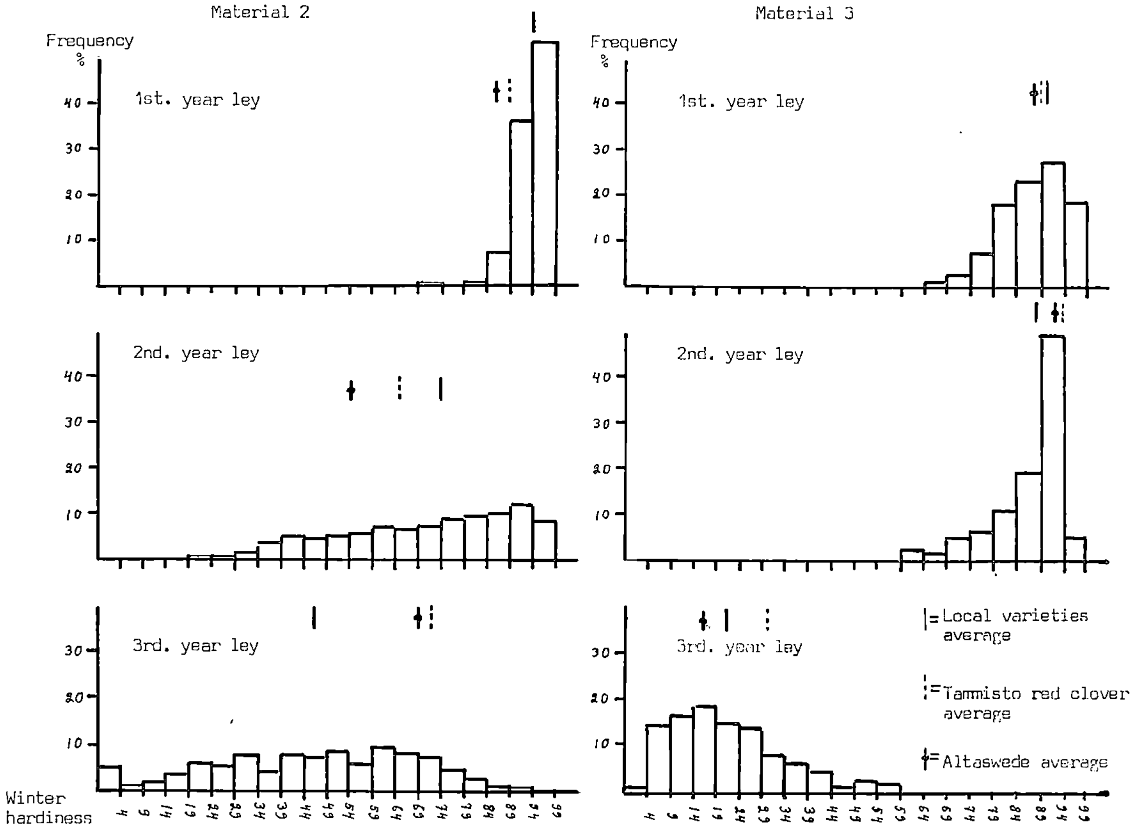


Fig. 2. Frequency distributions of winter hardiness of local varieties in variously aged leys in material 2 and 3.

year leys, r = 20***, +0,36***, and +0,23***; and in material 3, r = —0,15***, +0,15** and +0,13**.

Pohjakallio (1959) and Umareus (1963) found that the decrease in daylight as the days shorten generally increases the winter hardiness of northern red clover varieties. However this is not always so, because of the lack of genetic adaptability and because the biotypes of clover rot also influence hardiness. This was also apparent in the present study.

Yield

There were large annual variations in the yield (Fig. 3). The yield of material 2 was greatest in the first year ley and smallest in the second year (not the third as is usually the case and which occurred in material 3). This was due to ice and water damage and drought which weakened the 2nd year ley.

The average dry-matter yields and amount of raw protein in material 2 in all of the agricultural societies were, in the 1st year ley, greater than those of Tammisto red clover, but in material 3, only the dry-matter yields from agricultural societies 3, 6, and 5 were greater. However, in material 3, the raw protein yields of 10 different agricultural societies were greater than that of Tammisto red clover. In the 2nd year leys, the average material 2 yields of dry matter and raw protein from northern agricultural societies 13, 12, 14, 15, and 10 were

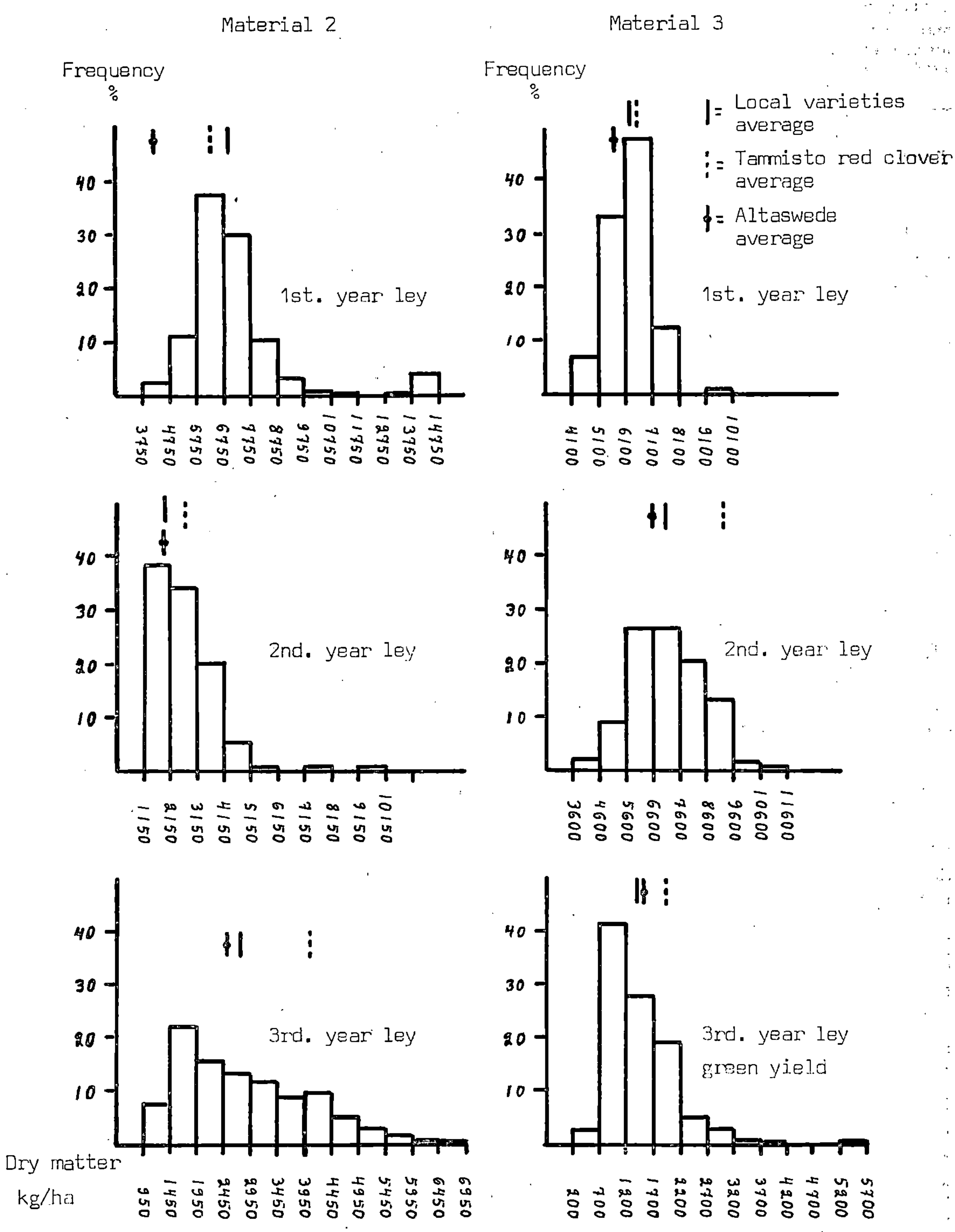


Fig. 3. Frequency distributions of dry matter yields of local varieties in variously aged leys in materials 2 and 3.

Table 5. Frequency distributions, percentage of local varieties with yield values similar to, higher than and lower than Tammisto and Altaswede in leys of various ages. (Dry matter yield, except for material 3 in 3rd year ley which was green yield.)

Position in order of yield	Material 2			Material 3		
	1st year ley	2nd year ley	3rd year ley	1st year ley	2nd year ley	3rd year ley
Equal to Tammisto	39,7	34,2	19,8	47,5	13,3	19,1
Higher than Tammisto	46,2	27,1	11,1	12,5	2,0	9,3
Lower than Tammisto	13,9	38,8	79,1	40,0	84,7	71,5
Equal to Altaswede	11,3	38,8	13,1	33,0	26,4	27,2
Higher than Altaswede	86,1	61,2	41,7	60,0	35,9	28,5
Lower than Altaswede	2,6	0,0	45,2	7,0	37,7	44,3

all greater than from Tammisto. In material 3, the dry matter and raw protein yields from Tammisto were greater than the average yields of the agricultural societies. In the 3rd year ley, Tammisto produced yields of raw protein and dry matter which were greater than all the average yields from the agricultural societies in material 2. In material 3, only the green yield was determined for the 3rd year ley. Only the average green yield of agricultural society 14 was larger than that of Tammisto red clover. The proportion of the local varieties which had a yield the same as or better than Tammisto declined, and the number of local varieties which had a poorer yield than Altaswede increased, as the leys increased in age (Table 5). Differences in yields between the various local varieties were also large (Table 6).

In material 2, the ranking order in terms of average dry-matter volume from the 1st to 3rd year leys was agricultural societies 12, 13, 10, and Tammisto red clover; and in terms of raw protein yields, agricultural societies 12, 13, 15, 14, and Tammisto (Fig. 4). In material 3, the largest dry-matter and raw protein yields were obtained from Tammisto red clover and clovers from agricultural societies 3, 5, and 4. Some local varieties which gave yields higher than Tammisto were found among each agricultural society's local varieties. Good winter hardiness by no means always implied a good yield.

The correlation between the latitude of the place of origin of a local variety and its yield was negative in 11 cases and positive in 5 cases. Five correlations were not statistically significant. The results obtained concerning the superiority of Tammisto red clover Altaswede, particularly in the 2nd and 3rd year leys, confirmed the results of earlier studies. The result that some of the local varieties gave greater yields outside their original area of cultivation due to good adaptability was also confirmed (Simola 1923, 1924, Valle 1938, 1958, 1964, Saloheimo 1939, Multamäki 1949, 1961, Honkavaara 1937, Anttinen 1959, Isotalo 1959, Ravantti 1961, 1965, Paatela 1962). Paatela's (1959) finding that the value of local varieties was partly overemphasized since some of them have poor yields was in accordance with the results obtained here. Some of the local varieties gave an even poorer yield than Altaswede, which shows that Altaswede performs better than its reputation implies under Finnish conditions.

Umareus (1953) found that the raw protein content of red clover increased as the amount

Table 6. The dry matter yield of the most productive and least productive local varieties.

	Dry matter yield kg/ha		
	1st year ley	2nd year ley	3rd year ley
Material 2			
Most productive local variety	11 850	9 000	5 560
Least productive local variety	3 230	200	460
Material 3			
Most productive local variety	8 430	9 610	(5 100)
Least productive local variety	3 280	2 660	(200)

( ) = green yield

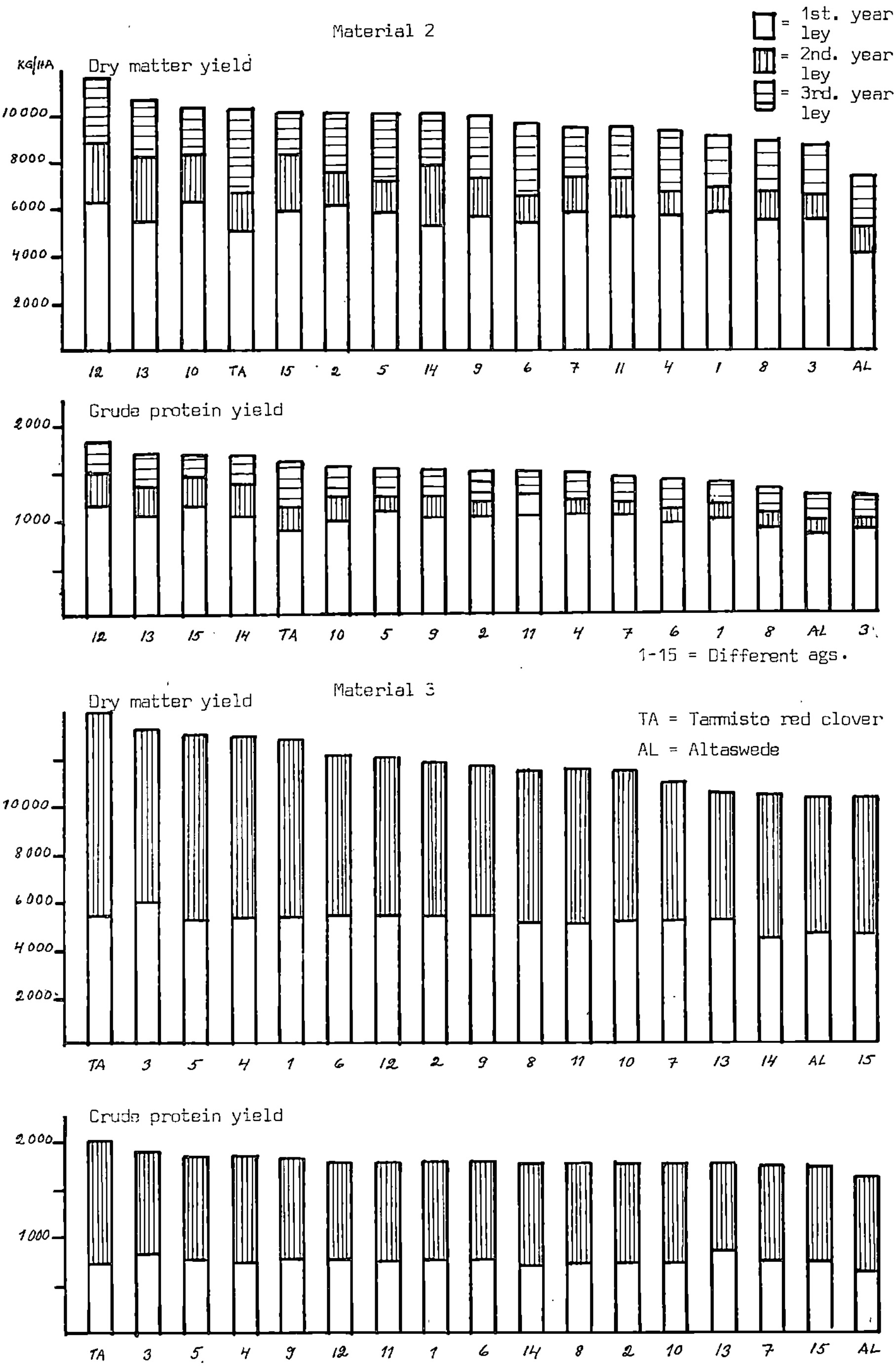


Fig. 4. Dry matter yield and crude protein yields of local varieties in material 2 and 3 in 1st.—3rd. year leys.

of daylight decreased. This was also partly discernible in this study as far as the northern local varieties were concerned; but northern varieties also suffered from the shortened daylight hours. Paatela (1962) found that a very significant negative correlation existed between the forage yield and the latitude of the place of origin of Finnish red clovers in southern Finland. This was also shown by Ravantti (1965), as well as partly by this study.

Leafiness

On average, Tammisto red clover produced more leaves than Altaswede or the local varieties (Table 7).

The five individual local varieties that produced the most leaves were also among the most hardy varieties and were among those that gave the greatest yields. Among others, Wexelsen (1937) and Nüesch (1960) have recommended the use of a scale of the amount of foliage produced as a method for selecting individuals to be used to increase yields (particularly raw protein yields).

Table 7. Analysis of leafiness in main yield of first year ley in material 3.

	Proportions of leaves, stems and flowers determined from 250 g of air-dried hay			
	Local varieties	Leaves (%)	Stems (%)	Flower heads (%)
Tammisto	—	41	48	11
Altaswede	—	34	44	22
Agricultural societies				
1. Province of Uusimaa	39	35	49	16
2. Swedish Agricultural Society of Uusimaa	54	32	51	17
3. Varsinais-Suomi	8	36	50	14
4. Satakunta	7	38	45	17
5. Province of Häme	22	37	49	14
6. East Häme	21	34	50	16
7. Häme-Satakunta	16	35	50	15
8. Kymenlaakso	44	36	50	14
9. North Carelia	6	37	49	14
10. Province of Mikkeli	74	35	48	17
11. Kuopio	33	35	49	16
12. Central Finland	18	34	49	17
13. South Pohjanmaa	4	29	50	21
14. Kajaani	5	36	46	18
15. Province of Oulu	39	35	47	18

Earliness and abundance of flower heads

Tammisto red clover was a later variety and Altaswede earlier than the local varieties of the agricultural societies, on average. The proportion of early local varieties increased as the ley increased in age. The earliness of Altaswede in relation to the Finnish materials had already been verified in earlier studies (Multamäki 1949, 1961, Ravantti 1960).

On average, Tammisto red clover had fewer and Altaswede more flower heads than the local varieties. Flower head formation showed great variation in leys of different ages in the same material and between different materials. As Paatela (1962) has demonstrated, this was apparently due to the flowering stage and weather conditions. Altaswede proved to produce greater yields than Tammisto in earlier seed cultivation trials (Ravantti 1960), so that the finding of this study of the abundant formation of flower heads in Altaswede was to be expected. Paatela (1962) had observed that northern local varieties produce more flower heads than those of southern Finland. The findings of Ravantti (1965 b) were almost completely opposite. This study did not provide a clear picture either way in this matter.

Local varieties resembling Altaswede

Of the local varieties investigated, 4,6 % were primarily Altaswede and 11,3 % were mixed or cross-bred with Altaswede (Table 8). The cross-breeds usually had poor winter hardiness and yields. However, of 44 local varieties, 3 of the 17 lots which resembled Altaswede and 4 lots of the Altaswede mixture were those

Table 8. Local varieties resembling Altaswede and those crossed or mixed with Altaswede. Percentages of the total numbers of local varieties.

Agricultural societies	Varieties resembling Altaswede % of lots	Varieties crossed or mixed with Altaswede % of lots
1. Province of Uusimaa ..	10,2	12,8
2. Swedish Agricultural Society of Uusimaa ...	7,4	12,9
3. Varsinais-Suomi	12,5	12,5
5. Province of Häme	—	9,1
6. East Häme	—	4,7
7. Häme-Satakunta	—	12,5
8. Kymenlaakso	15,9	11,3
9. North Carelia	—	16,6
10. Province of Mikkeli ...	1,4	8,1
11. Kuopio	3,0	21,2
12. Central Finland	—	33,3
15. Province of Oulu	—	2,5
Whole material/total	4,6	11,3

which had the best winter hardiness values and yields among the local varieties. The cultivators had evidently followed the advice of the extension agents not to produce seed from Altaswede because there were only a very few lots similar to Altaswede or cross-bred with it in the material.

Differences between and within agricultural societies

Although the agricultural societies were represented by a large and varied number of local varieties, the variant analyses computed in the study both between and within agricultural societies were statistically reliable.

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SELOSTUS

Puna-apilan suomalaisten paikallismuotojen talvenkestävyys ja satoisuus Etelä-Suomessa Hankkijan Kasvinjalostuslaitoksen Anttilan koetilalla 1962—66.

SAIJA RAVANTTI

Maatalouden tutkimuskeskus

Puna-apilan viljely väheni Suomessa 1960-luvulla typellä voimakkaasti lannoitettujen heinänurmien yleistyessä. Nyt 1980-luvun alussa harkittaessa puna-apilan viljelyn uudelleen laajentamista on katsottu aiheelliseksi esittää pääpiirteitä tekijän julkaisemattomasta tutkimuksesta: Puna-apilan kotimaisten kauppasiemenerien viljelyarvo Hankkijan Kasvinjalostuslaitoksen Anttilan koetilalla vuosina 1962—66. Tulokset antavat pohjatietoa siitä, onko puna-apilan laajeneva viljely perustettava vain kotimaisten lajikkeiden varaan tai olisiko edistettävä myös vielä mahdollisesti viljelyssä olevien hyvien paikallismuotojen viljelyä.

Tutkimus selvitteli vuosina 1960 ja 1961 tuotettujen viralliseen siemenkauppaan hyväksyttyjen 390 suomalaisen paikallismuodon viljelyarvoa rehukasvina Tammiston puna-apilaan, kokeiden mittarilajikkeeseen ja Altaswedeen, vuosien 1940—62 päätuontilajikkeeseen verrattuna. Paikallismuotoja oli 15 maanviljelysseuran alueelta. Enemmistö aineistosta 75,2 % oli sisämaan kauppasiemenen alituotantoalueelta ja vain 24,8 % sen päätuotantoalueelta. Sisämaassa kyllä siemenviljeltiin puna-apilaa, mutta usein vain omaan käyttöön. Aineistot käsiteltiin maanviljelysseuroittain (lyh. mvs.) kolmeen aineistoon jaettuna.

Paikallismuotojen enemmistö oli kylvökesänä Tammiston puna-apilaa nopeammin, mutta Altaswedeä hitaammin kehittyvää. Paikallismuotojen kotiseudun leveysasteen riippuvuudet kehitysnopeusmuuttujista olivat negatiivisia ja tilastollisesti erittäin merkitseviä.

Nurmen vanhetessa väheni Tammiston puna-apilaa talvenkestävämpien ja Altaswedeä heikkosatoisampien paikallismuotojen osuus. Kolmannen vuoden nurmessa (lyh. 3. v.n:ssa) oli Tammiston puna-apilaa talvenkestävämpiä kahdessa aineistossa 8,0 % ja 14,1 % sekä Altaswedeä huonommin talvenkestäviä 76,0 % ja 31,6 % paikallismuodoista. Keskimäärin talvehtivat parhaiten pohjoisten mvs:jen paikallismuodot, vaikka yksityisiä hyvin talvehtivia paikallismuotoja olikin kaikkien mvs:jen paikallismuodoissa. Satoisuuden vuosivaihtelut olivat suuret. Tammiston puna-apila oli kaikissa nurmissa Altaswedeä satoisampi. Aineistossa 2 1—3.v.n:ssa oli keskimääräinen suurempien kuiva-ainesatojen järjestys Keski-Suomen, Etelä-Pohjanmaan, Mikkelin läänin mvs:jen apilat ja Tammiston puna-apila. Raakavalkuaissadoissa oli lisäksi Kajaanin ja Oulun läänin mvs:jen apilat Tammiston puna-apilaa keskimäärin satoisampia. Aineistossa 3 oli Tammiston puna-apilan kuiva-aine- ja raakavalkuaissato mvs:jen keskisatoja suurempi. Nurmen vanhetessa väheni Tammistoa satoisampien ja Altaswedeä vähäsatoisampien paikallismuotojen määrä. 3. v.n:ssa oli kahdessa aineistossa Tammiston puna-apilan satoisuusluokkaa satoisampia paikallismuotoja 11,1 % ja 9,3 % sekä Altasweden satoisuusluokkaa pienisatoisampia 45,2 % ja 44,3 %. Joitakin Tammiston puna-apilaa satoisampia paikallismuotoja oli joka mvs:n paikallismuodoissa. Hyvä talvenkestävyys ei aina merkinnyt hyvää satoisuutta.

Paikallismuodon kotiseudun leveysasteen ja satojen riippuvuudet olivat 11 tapauksessa negatiivisia, 5 positiivisia. Neljä riippuvuutta oli ilman tilastollista merkittävyyttä.

Tammiston puna-apila oli keskimäärin lehtevämpi kuin Altaswede ja paikallismuodot. Viisi aineiston lehtevintä yksityistä paikallismuotoa kuului samalla aineiston talvenkestävimpiin ja satoisimpiin paikallismuotoihin.

Tammiston puna-apila oli myöhäisempi ja Altaswede aikaisempi kuin mvs:jen paikallismuodot keskimäärin. Vaikka mykerönmuodostus vaihteli melkoisesti, oli Altasweden nykerönmuodostus keskimäärin mvs:jen paikallismuotoja runsaampaa. Viljelijät olivat kuitenkin melko hyvin noudattaneet kehoitusta olla tuottamatta siementä Altawedestä, sillä vain 4,6 % paikallismuodoista oli etupäässä Altaswedeä ja 11,3 % sen kanssa risteytyneitä.

Vaikka eri mvs:a edusti vaihteleva määrä paikallismuotoja, olivat tutkimuksen varianssianalyysit mvs:jen välillä ja sisällä tilastollisesti luotettavia.

Esillä oleva tutkimus osoitti, että 1960-luvun alkupuolella viljeltiin Suomen eri puolilla monia rehukasveina arvokkaita paikallismuotoja. Mikäli ne ovat edelleen viljelyssä pienessä mitassa, olisi niiden viljelyn laajentamista harkittava.

ANNALES AGRICULTURAE FENNIAE, VOL. 19: 156—163 (1980)

Seria AGRICULTURA N. 66 — Sarja PELTOVILJELY n:o 66

OBSERVATIONS ON THE FOOD PLANTS OF THE HONEYBEE

PENTTI TEITTINEN

TEITTINEN, P. 1980. **Observations on the food plants of the honeybee.** Ann. Agric. Fenn. 19: 156—163. (Agric. Res. Centre, Satakunta Exp. Sta., SF—32810 Peipohja, Finland.)

The visits by honeybees to the flowers of certain honeybee food plants were recorded and the cultivation technique of the phacelia (*Phacelia tanacetifolia*) investigated at the Satakunta experimental station.

In 1960—1968 the red clover was visited by an average 341 honeybees/100 m^2. Three quarters of these were pollinators. In 1960—1961 and 1964—1968 honeybees accounted numerically for 50 per cent of all red clover pollinators and carried out 28 % of all red clover pollination.

A comparison of bee plants showed that borage (*Borago officinalis*), phacelia and white melilot (*Melilotus albus*) attracted more honeybees than did the clovers.

In the cultivation of phacelia a distance of 12,5 or 25 cm between rows and a seed rate of 5—8 kg/ha can be used. Sown in early May, flowering begins 8 weeks, and sown in late May 6 weeks, after sowing. The flowering period lasts 27—31 days. The nitrogen fertilizer input which produces the highest yield of flowers is about 50 hg/ha. Chemical weed control cannot be used. A seed yield can also be harvested from the phacelia.

Index words: Bee plants, red clover pollination, phacelia.

INTRODUCTION

The significance of honeybees for the pollination of many cultivated plants is considerable. This is particularly true in agricultural areas where there are few natural pollinators. On the other hand, honeybees may suffer from a shortage of food plants owing to intensive cultivation centred mainly on cereal crops. In order to place apiculture on a sound footing the supply of food for honeybees should be secured even when the cultivation of insect-pollinated plants is small. In the '60s the cultivation of clover began to decline rapidly and the area under turnip rape showed no signs of increasing, either. The soil bank scheme introduced towards the end of the decade, which under a later amendment permitted beekeeping, appeared to open up prospects for an expansion of apiculture through the cultivation of bee-pollinated plants on fields covered by the soil bank scheme, especially in central and eastern Finland — areas poorly exploited in apicultural terms.

In the circumstances it seemed necessary to look into the value and cultivation prospects of cultivable food plants for honeybees.

From the very start, therefore, the apiary of the Satakunta experimental station has been used in investigating the value and potential of honeybee food plants.

MATERIAL AND METHODS

The size of the apiary at the Satakunta experimental station varied annually between 8 and 15 colonies. The honeybees were of Italian origin. The hive was the Langstroth multiple-storey type. All the findings indicative of the value of bee plants are based on a count of the number of visits by honeybees to the flowers.

The plants covered by the research were sown in plots 25—50 m² in area. The count was taken daily during the flowering period at about 2 p. m. for an area of 5 to 15 m² of every plant stand. With red clover the count was also taken in certain years for plots set apart from the area under cultivation.

RESULTS AND DISCUSSION

Red clover as a bee plant

Pollination observations on red clover (*Trifolium pratense*) were first made as long ago as summer 1960 before the experimental station had its own apiary. There was a private apiary comprising 3 to 5 colonies some 200 metres from the border of the experimental station's cultivated area right up to 1961. In 1962 and 1963 there were no honeybees at all in the immediate surroundings, a fact reflected in the observation findings. Honeybees were introduced at the experimental station on June 19, 1964, and were therefore capable of nectar collection the same summer during the flowering season of the red clover. The distance of the observation areas from the experimental station apiary ranged between 100 and 400 metres. The area of the observation areas varied annually between 48 and 210 m².

Visits by honeybees to red clover varied widely from one year to the next, between 9 and 977 visits per 100 m² (Table 1). It has not proved possible to explain the reasons underlying the annual fluctuation from the present material. The number of visits and the abundance of nectar and, on the other hand, the development stage of the honeybee colony are causally

Table 1. Visits by honeybees to red clover during the flowering period.

Year	Honeybees			Bumblebees		Pollination period	
	total number per 100 m²	pollinators %	proport. of all pollinators %	total number per 100 m²	pollinators %	starting date	duration d
1960	225	100	26	707	93	6/7	33
1961	167	39	18	383	54	8/7	38
1962	0	—	—	702	39	28/7	40
1963	15	0	0	1 339	29	11/7	35
1964	26	34	3	341	74	16/7	41
1965	195	99	56	165	91	18/7	45
1966	903	33	30	2 276	30	5/7	41
1967	977	100	84	177	93	19/7	18
1968	557	100	76	299	59	9/7	38
1960—1968 ..	341	..	..	599	..	13/7	37
1960—1961, 1964—1968	436	75	50	..	..	..	..

Table 2. Stage of flowering (0—10) of red clover on the first visits by honeybees (a) and bumblebees (b).

Year	Flowering of red clover at the start of pollination	
	(a)	(b)
1960	4	1½
1961	3+	1+
1962*	—	2
1963*	—	1+
1964	3½	1½
1965	1+	5+
1966	4—	1—
1967	3	4+
1968	4½	2

*) Honeybee colonies absent from the immediate surroundings.

related (SKOVGAARD 1952, PAATELA and HEINRICHS 1959).

In some years red clover was very significant for honey bees — and, of course, vice versa. Honeybees began to visit red clover comparatively late — on July 18, on average. At this stage the flowering of red clover was already well under way, often with at least a third of the flowers open (Table 2, Fig. 1). Honeybees normally began visiting red clover later than bumblebees, although 1965 and 1967 proved exceptions in this respect. During 1967 honeybees began to visit red clover somewhat earlier and during 1965 considerably earlier than bumblebees. In these years the number of bumblebees was lower than average. This and the late appearance of bumblebees seem to indicate that either only a few fertile queen bumblebees had been left to winter during the previous autumn or else the wintering had failed. In the circumstances honeybees were of greater importance as pollinators of red clover (VALLE 1959, 1965).

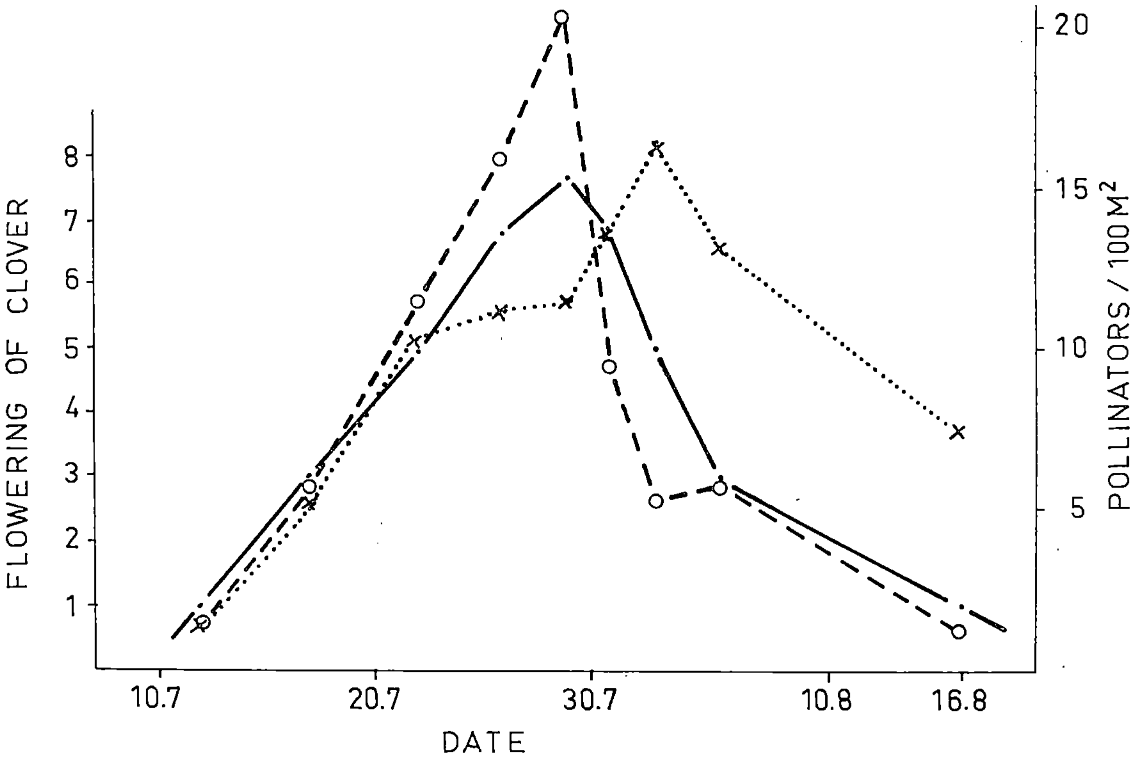

Fig. 1. Flowering of red clover (.———.) and visits by honeybees (o — — — — o) and bumblebees (+ . . . . +) to red clover on the average in 1960—1968.

In red clover the honeybees gather pollen or nectar or both of them (VALLE and BERGT 1965). The observations did not monitor whether honeybees visited red clover for nectar or pollen. On the other hand, observations were made on whether honeybees acted positively or negatively. The positives were reckoned to include all honeybees which pushed their way into the flower between the petals, the negatives those which extracted nectar through a hole at the base of the corolla tube. The holes are normally made by *Bombus lucorum*, a species of bumblebee. In several years honeybees began their visits to red clover as positives, but suddenly changed their behaviour to that of negatives. The number of negative honeybees was highest when negative bumblebees were abundant (Table 1).

The nectar in red clover is often difficult to reach, lying deep in the corolla tube beyond easy reach of the tongue of the honeybee. Visits by the honeybee to clover therefore take longer than those by the long-tongued bumblebee, for example. It is estimated that pollination by 2,5 honeybees is required to achieve the pollination efficiency of one bumblebee (SKOVGAARD 1952). Calculated on this basis, the observation material for 1960—1961 and 1964—1968 indicates that honeybees accounted for an average 28 % of the pollination of red clover. The proportion of honeybees was nearly the same at Tikkurila (VALLE 1965).

Owing to this difficulty with the accessibility of the nectar red clover is not the best plant for bees. Presumably for just this reason its competitive ability is poor and it can only attract honeybees when other competing plants are few. In terms of the cultivation of red clover, however, honeybees may still be of very great importance. Efforts to increase visits to red clover by honeybees have been made using scent feeding (VALLE 1947). Although this method has indeed produced results, efforts to increase its use have failed. The introduction of colonies in the clover field itself is the simplest way of increasing the honeybees' contribution to the pollination of red clover. It is certainly also possible to improve the accessibility of nectar and increase the activity of honeybees in relation to red clover by breeding of both honeybees and clover.

A comparison of bee plants

With a view to comparing certain annual and perennial bee plants, tests were devised to record the appearance of pollinators in 1969, 1971, 1973, 1975 and 1979. The test plants were phacelia (*Phacelia tanacetifolia*), white melilot (*Melilotus albus*), white clover (*Trifolium repens*), alsike clover (*T. hybridum*), borage (*Borago officinalis*) and buckwheat (*Fagopyrum sagittatum*).

In the first test in 1969 a visual estimate of honeybee density was made without actually counting the number of individuals. Observations showed plenty of honeybees on phacelia, some on white melilot and white clover but few on alsike.

In the 1971 test, honeybees visited phacelia most (Table 3). In the 1973 test the most attract-

Table 3. Bee plant comparison test findings.

Plant	Flowering		Honey-bees number/100 m² d	Seed yield kg/ha	Florets mill. units per m²
	starting date	duration d			
1971					
Phacelia	3/7	28	274	472	9,70
White melilot .	2/7	34	105	616	7,86
White clover ..	20/6	16	236	109	11,72
Alsike clover .	24/6	25	231	385	14,12
1973					
Phacelia	4/7	28	173	39	..
White melilot .	27/6	37	289	369	..
White clover ..	26/6	38	151	166	..
Alsike clover .	28/6	36	147	110	..
1975					
Phacelia*	2/7	29	291	..	..
Borage**	22/7	24	515	..	..

*) sown 9/5
**) sown 30/5

ive plant turned out to be the white melilot. The honeybee density on phacelia was again higher than those on the clovers. The number of phacelia flowers remained low for some reason, and this was reflected in a poor seed yield.

The 1975 test set out to compare borage and buckwheat with phacelia. The buckwheat stand froze during the spring frosts, however. The sowing of borage was delayed and the flowering period therefore came later. The plant attracted a substantial number of honeybees.

In 1979 phacelia, borage and buckwheat were sown in adjacent plots and visits by honeybees were counted on twelve days during the flowering period. The following honeybee densities were recorded:

phacelia	171	visits/100 m²d
borage	461	»
buckwheat	62	»

White melilot, borage and phacelia were the plants most favoured by honeybees during these tests. The white melilot is a perennial whose wintering in Finnish conditions is uncertain. The cultivation technique applied to borage, an annual, should be investigated further. An account of the experience gained from the cultivation technique applied to phacelia is given below.

Phacelia cultivation technique

Phacelia has been shown by both tests and practical cultivation to be a bee plant highly favoured by honeybees. As its cultivation technique appeared relatively simple and the honey obtained from its nectar was known to be good in terms of both aroma and consistency, field tests were undertaken to investigate the cultivation technique of the phacelia more closely. The parameters investigated were the time of sowing, seed rate, distance between rows, use of nitrogen fertilizer and weed control.

Table 4. Phacelia sowing time test findings.

Sown	From sowing to start of flowering, d	Flowering starting date	Flowering duration, d	Seedlings number/m²	Honeybees number/100 m²d	Seed yield kg/ha
1972						
13/5 ...	48	30/6	30	31	424	320
18/5 ...	45	2/7	29	46	541	441
23/5 ...	43	5/7	37	35	368	416
28/5 ...	41	8/7	38	38	355	576
2/6 ...	41	13/7	35	28	345	405
1973						
27/4 ...	57	23/6	31	..	418	155
7/5 ...	50	26/6	31	..	516	117
17/5 ...	47	3/7	30	..	470	62
28/5 ...	42	9/7	27	..	423	82
1974						
3/5 ...	59	1/7	29	..	322	..
8/5 ...	57	4/7	27	..	255	..
13/5 ...	55	7/7	26	..	201	..
18/5 ...	54	11/7	27	..	191	..
23/5 ...	53	15/7	30	..	205	..
28/5 ...	57	24/7	27	..	223	..
1975						
30/4 ...	61	30/6	29	..	354	..
5/5 ...	59	3/7	29	..	335	..
10/5 ...	57	6/7	29	..	400	..
15/5 ...	54	8/7	29	..	457	..
20/5 ...	54	13/7	27	..	525	..
26/5 ...	49	14/7	28	..	491	..

The earlier the sowing, the earlier the start of the flowering period for phacelia (Table 4). However, the period between sowing and flowering was longer for the earlier sowings than for the later ones. The number of visits by honeybees varied without any particular pattern (Fig. 2). According to observations on the development of honeybee colonies and findings on the weight of accumulated honey, late June was shown in several years to be a period when the increase in hive weight was negligible. The reason underlying this declining enthusiasm for collecting nectar may be preparations with a low-yield season when good wild bee plants are only just beginning to flower. Getting the phacelia to flower before the end of June would therefore be a major achievement. This has failed, however, except

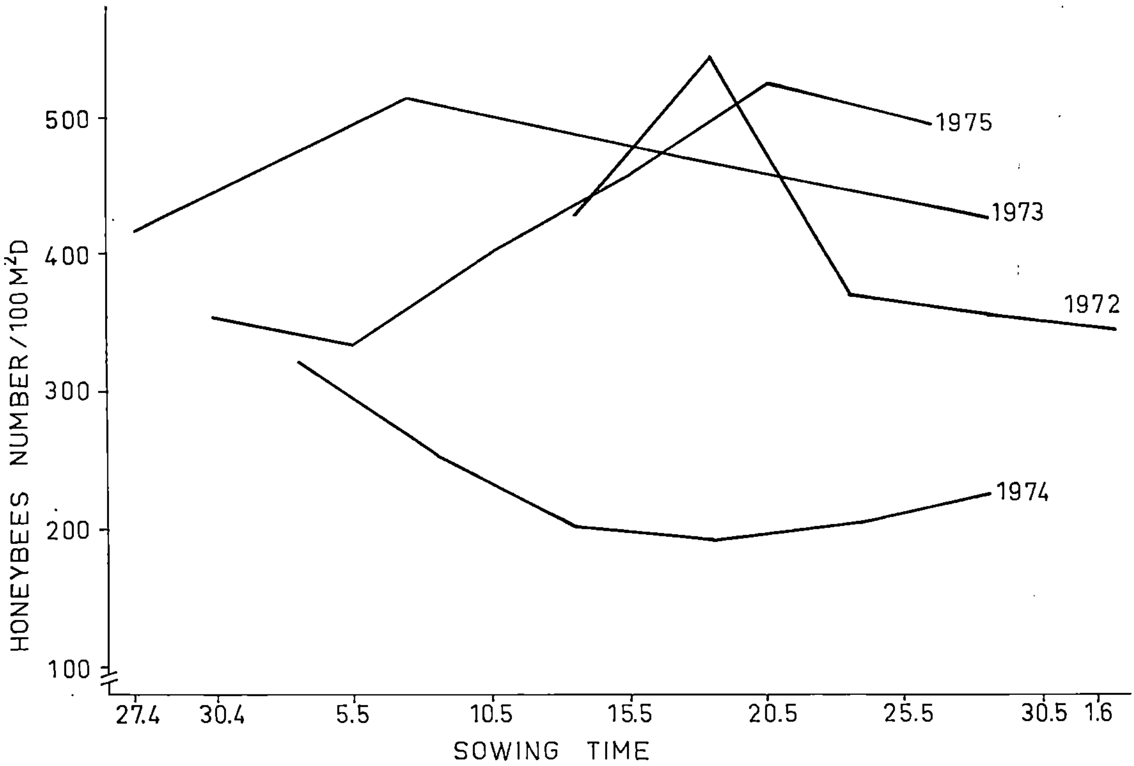

Fig. 2. Honeybees number/100 m²d in different years at the phacelia sowing time tests.

in years when sowing was completed by April-May at the latest. Sowing as early as this is not always possible.

Efforts to speed up the early growth of phacelia by means of preliminary treatment of the seeds have failed. Keeping the seed in water or succinic acid solution for 24 hours during the test conducted in 1972 in no way brought the beginning of the flowering period forward compared with untreated seed. On the other hand, sowing late in the autumn produced specimens which began flowering early in June. The phacelia does not normally survive winter. It is not, it is true, susceptible to frost, and wintering diseases do not occur in it. The death of seedlings — and older plants — during the winter is probably due to the plant's inadequate stock of nutrients. Sown very late, when germination has only just begun before the onset of winter, phacelia has been made to winter and begin growing early in the spring. Even then only a small proportion of the specimens sown survived the winter.

A seed rate of 5—8 kg/ha for phacelia proved best in the tests described (Table 5), for it produced more flowers and attracted more honeybees than lower and higher seed rates. Sowing can be carried out with a seed drill, in which case the distance between rows is normally 12,5 cm. This distance has proved best for visits to flowers by honeybees (Table 5). A distance of 25 cm between rows was not significantly less favourable. This distance is achieved when the sowing is carried out with every other drill coulter. Even larger distances between rows have been used with satisfactory results (LAAKSONEN 1970, LOTTANEN 1973). The seed of the phacelia is small, the weight

Table 5. Phacelia seed rate and row separation test findings.

Seed rate kg/ha	Distance between rows, cm	Flowering starting date	Flowering duration, d	Honey-bees number/100 m²d	Plant specimens number/m²	Flowers number /m²
1970						
5	12,5	1/7	28	..	116	84 328
25	12,5	29/6	24	..	336	35 144
1971						
2,5	25	..	..	..	45	32 240
5	12,5	..	..	..	132	58 570
1972						
2,5	12,5	14/7	36	505	..	..
5	12,5	13/7	36	542	..	..
2,5	25	15/7	35	452	..	..
5	25	13/7	37	474	..	..
7,5	12,5	13/7	37	523	..	..
1973						
2,5	12,5	28/6	27	140	..	..
5	12,5	28/6	27	189	..	..
2,5	25	28/6	27	102	..	..
5	25	28/6	27	180	..	..
7,5	12,5	28/6	27	194	..	..

Table 6. Phacelia nitrogen fertilizer test findings.

Nitrogen fertilizer kg/ha	Flowering starting date	Flowering duration, d	Honey-bees number/100 m²d	Seed yield kg/ha
1972				
50	14/7	35	554	436
100	14/7	41	481	375
1973				
0	28/6	27	189	22
100	28/6	27	321	54

of a thousand seeds being no more than 1,4 to 1,5 g, so the seed must be sown in shallow furrows.

Nitrogen fertilizers should be used moderately on phacelia. Care should be taken that the supply of nitrogen is adequate, but excessive nitrogen will lodge the plant stand, and flowering will suffer. The best test results are obtained with about 50 kg/ha of nitrogen (Table 6).

The eradication of weeds is one of the greatest problems encountered in the cultivation of phacelia. Weeds are particularly harmful when seed is being taken from the plant stand. Initial growth in phacelia is not very rapid, especially if sowing is early. Then again, inadequate moisture for germination during later sowings may result in insufficient coverage of the plant stand. In both cases weeds have easy access to growing space. The fat hen (*Chenopodium album*), in particular, is a troublesome weed because separation of its seed from the seed of the phacelia is very time-consuming. The two tests with chemical agents (trifluralin, napropamid, paraquat/monolinuron, bentatson, propachlor) produced partly contradictory results, and neither proved unconditionally satisfactory. When the distance between rows is great, weeds can be removed by hoeing (LOTTANEN 1973). If a seed crop is also taken from the phacelia, selection of a weed-free site is recommended.

The seed harvest was carried out with a combine harvester without difficulty.

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SELOSTUS

Mehiläisten ravintokasveja koskevia havaintoja

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Maatalouden tutkimuskeskus

Satakunnan koeasemalla on seurattu mehiläisten käyntejä eräiden mehiläisten ravintokasvien kukissa ja selvitetty hunajakukan (*Phacelia tanacetifolia*) viljelytekniikkaa. Mehiläishavainnot on tehnyt mahdolliseksi ylijohtaja Jouko Vuorisen aloitteesta koeasemalle v. 1964 hankittu mehiläistarha. Tarhan koko on ollut vuosittain 8—15 yhteiskuntaa. Mehiläiset ovat olleet italialaista rotua.

Puna-apilalla on v. 1960—1968 käynyt mehiläisiä keskimäärin 341 kpl/100 m^2 yhteensä 37 vuorokautta kestäneen kauden aikana. Mehiläiset ovat tulleet puna-apilaan kimalaisia myöhemmin ja useimmiten vähintään kolmasosa apilan kukista on silloin ollut avautunut. Mehiläisistä on pölyttänyt kolme neljäsosaa. Mehiläiset ovat usein muuttaneet työskentelytapansa ryöstäväksi sen jälkeen kun ryöstäviä kimalaisia on tullut kasvustoon. Pölyttävät mehiläiset ovat muodostaneet lukumääräisesti 44 prosenttia kaikista pölyttäjistä v. 1960—1968. Jos laskelmasta jätetään pois vuodet 1962 ja 1963, jolloin koeaseman lähiympäristössä ei ollut mehiläisyhteiskuntia, mehiläisten osuus kaikista pölyttäjistä on ollut 50 prosenttia. Jos oletetaan, että 2,5 mehiläistä vastaa pölytysteholtaan yhtä kimalaista, mehiläiset ovat havaintokauden aikana suorittaneet 28 prosenttia puna-apilan pölytyksestä.

Mehiläiskasvien vertailussa ovat purasruoho (*Borago officinalis*), hunajakukka ja valkomesikkä (*Melilotus albus*) osoittautuneet apiloita paremmiksi houkuttelemaan mehiläisiä.

Yksivuotisen hunajakukan kukintakausi on alkanut heinäkuun alussa ja se on tavallisesti kestänyt 27—31 vuorokautta. Kukinnan alkua on voitu jonkin verran aikaistaa käyttämällä aikaista kylvöä. Kukintakauden pituuteen kylvöajalla ei ole ollut vaikutusta.

Koetulosten ja 0,5—1,5 ha:n suuruisilta viljelmiltä useana vuonna hankitun käytännön kokemuksen perusteella hunajakukalle voidaan antaa seuraavat viljelyohjeet:
Hunajakukka voidaan kylvää viljankylvökoneella joko jokaisella tai joka toisella vantaalla. Sopiva kylvömäärä on 5—8 kg/ha. Siementä tuotettaessa on syytä käyttää vielä suurempaa kylvömäärää rikkakasvien tukahduttamiseksi, vaikka kukkien määrä silloin vähenee. Hunajakukan siemen on pientä, joten kylvö on suoritettava matalaan. Lannoituksessa noin 50 kg/ha typpeä on riittävä, jotta lakoutumista ei tapahtuisi. Siemenen korjuu voidaan suorittaa leikkuupuimurilla.

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Seria HORTICULTURA N. 45 — Sarja PUUTARHAVILJELY n:o 45

EFFECTS OF SOIL TEMPERATURE ON NUTRIENT TAKE-UP, GROWTH, AND YIELD IN THE STRAWBERRY

EEVA LAURINEN and JAAKKO SÄKÖ

LAURINEN, E & SÄKÖ, J. 1979 **Effects of soil temperature on nutrient take-up, growth, and yield in the strawberry.** Ann. Agric. Fenn. 19: 164—172. (Agric Res. Centre, Inst. Hortic., 21500 Piikkiö 4, Finland).

Investigations were carried out at the Institute of Horticulture, Piikkiö, into the effects of fertilization and soil temperature on the take-up of nutrients, growth, and yield in the strawberry. The investigation was carried out both on open ground and under netting of fine-meshed artificial fibre. In addition to an unfertilized control, two levels of fertilization were applied: the spring fertilization consisted of a mixed preparation, in which the main nutrient content was 55 and 110 kg/ha of N, 55 and 110 kg/ha of P_2O_5, and 110 and 220 kg/ha of K_2O; further fertilization, applied after the yield had been harvested, consisted of calcium saltpetre, containing 23,3 and 46,6 kg/ha of N. The soil around the strawberry roots was warmed during the growth period by means of an electric cable buried at about 10 cm depth.

The fertilization applied did not lead to any increase in strawberry yield; the highest yield was obtained from the plants which were unfertilized. The temperature increase obtained with the electric cables during the growth period was on average 2—4 °C, with a slightly higher rise under netting than in the open. Heating advanced flowering and harvest by a few days, but had no effect on yield quantity; the quality of the yield, on the other hand, depreciated with heating, especially under netting. The incidence of grey mould increased, and the proportion of small berries in the harvest also increased. The higher soil temperature had no effect on the transfer of nutrients from the soil to the plants nor on the quantities of nutrients present in leaves or fruit.

The conditions obtained under netting, in terms of temperature, light, and moisture, were unfavourable to the strawberry. The yield obtained from plants under netting was on average only 56 % of that obtained in the open.

Index words: Strawberry fertilization, soil temperature.

INTRODUCTION

It has been established, both in investigations in Finland and elsewhere, that the nutrient needs of the strawberry are relatively low, and that the addition of fertilizer does not necessarily result to an increase in yield. In most cases, excessive fertilization has in fact been found to induce a reduction in yield, particularly in the case of nitrogen fertilization, where overdosing leads to luxuriant growth.

The fertilization of strawberry is commonly based on the soil and leaf analysis. The significance of leaf analysis in the study of strawberry nutrient requirements has expanded, but its usefulness has found to be limited in certain respects. The nutrient content of the leaves displays fluctuations, both between varieties and also from year to year and between different locations, which have not been shown to exercise any immediate effect on the quantity of the yield. Nutrient transfer from the soil to the plant is also affected by the moisture and temperature conditions prevailing at each individual site.

The Institute of Horticulture in Piikkiö, Finland, layed out a series of experiments in order to investigate the fertilization requirements of the strawberry. The variety used was the widely cultivated Sengana. Experiments carried out in 1962—64 showed that increasing levels of nitrogen or potassium fertilization had no distinct effect on yield, although the levels of fertilization were reflected in the nutrient content of the leaves (Säkö 1974). The findings from these experiments also included the luxuriant growth consequent on nitrogen fertilization and the associated incidence of grey mould (*Botrytis cinerea*). In the 1967—69 experiment, the effect of a double administration of calcium saltpetre fertilizer, and the spraying of urea fertilization, during growth, was investigated; the differences in yield obtained were however insignificant, despite the fact that prior to fertilization the soil had been nitrogen deficient. In both years, the highest yield was obtained from the unfertilized control (Säkö 1974).

This investigation of the factors affecting growth and yield in the strawberry was continued in 1971—74 with a study both of the impact of increasing levels of fertilization on yield, and of the reactions of the plants to the raising of the soil temperature. The significance for strawberry growth of the micro climatical conditions produced under protective netting were also investigated. The results of this experiment are set out below.

MATERIAL AND METHODS

The experiment was set up in spring 1971, on a gentle southerly slope. The soil was coarser fine sand, and before planting, a 5 cm layer of limed peat was spread over this. The variety used was Sengana.

In order to investigate micro climatical conditions, a netting structure was set up on one side of the experimental area, 9×4 m in size. This was constructed using a fine-meshed artificial fibre material being first erected at the beginning of the experiment in spring 1971, with the netting being removed from its frame during the wintertime. A revolving thermometer was set up both in the open and under the netting in order to record the temperature during the period of growth.

In order to investigate the significance of soil temperature, two earth-warming cables were buried underground, in the open and under the netting (Lvssn 3,0 Ω/m, 10 W/m). The cables were placed 15 cm apart from each other, on either side of the strawberry plants, at a depth of about 10 cm. The heating was switched on at the beginning of growth, in the main at the end of April, and was disconnected at the beginning of October when growth ceased. The temperatures were recorded by means of earth thermometers buried at a depth of around 10 cm.

Fertilizer was administered twice during growth. The spring fertilization was carried out once growth had commenced in spring, using a fertilizer compound. The second fertilization, with calcium saltpetre, was administered in August after the yield had been harvested. There was an unfertilized control, and two levels of fertilization, as indicated below:

Mixed fertilizer	Calcium saltpetre
500 kg/ha	150 kg/ha
(main nutrient content	(nutrient content
N 55—P_2O_5 55—K_2O 110)	N 23,3)
1 000 kg/ha	300 kg/ha

Soil samples were taken from all the treatments annually in the spring, before fertilization. The fruit samples were taken during the harvest, and the leaf samples immediately after the end of the harvest, in the first or second week of August, before the autumn fertilization.

RESULTS

Open vs. netting cultivation

The conditions under the netting differed from those in the open. The tight-meshed netting evened out fluctuations in the air temperature, so that the minimum and maximum temperatures recorded in the open during the growth period show a wider range than those under the netting. The netting also, however, inhibited the warmth of sunshine, and retained the overnight coolness, with the results that the overall temperatures under the netting for the growth period remained lower than those in the open (Table 1). The quantity of solar light under the netting also remained lower.

This micro climate inside the net did not prove to be advantageous to the strawberry, and the yield obtained from the plants under the netting was lower every year than that obtained in the open (Table 2), being on average only 56 % of the latter. The reason for these poor yields under the netting are to be found in the temperature and light conditions outlined above, which were unfavourable to the formation of flower buds in Sengana at the end of the season. Pollenization of the plants may also have been better in the open, since there were no differences in the timing of flowering. The foliage of the plants under the protective netting remained moist longer than in the

Table 1. Temperatures at 10 cm depth in the soil and at the height of the strawberry plants, in the open and under netting: mean monthly temperatures, 1971—1974.

	Temperature in the soil 1971—1974				Air temperature 1971			
	Heated bed		Unheated bed		*) at 8 and 14		*) at 22 and 2	
	In the open	Under netting	In the open	Under netting	In the open	Under netting	In the open	Under Netting
	mean °C				mean °C			
May	10,9	12,3	8,4	7,7				
June	16,3	18,5	14,3	13,9	19,2	18,4	12,3	12,3
July	19,1	21,7	17,5	17,3	23,0	19,4	15,1	12,3
August	17,7	20,1	15,5	15,4	19,9	18,7	15,3	12,3
September	13,2	15,8	10,4	10,6	14,6	13,9	11,0	7,7
mean	15,4	17,7	13,2	13,0	18,9	17,3	13,1	10,9

Note. The temperature at 2, 8, 14 and 22 o'clock.

Table 2. Strawberry yield, in the open and under netting, at three levels of fertilization, on unheated and heated beds, 1972—74.

Variety: Sengana. Planting density: 0,35 × 0,80 cm; area of both the open-air and netting treatments, 4,48 m.
Fertilization: Unfertilized
500 kg/ha mixed fertilizer+150 kg/ha calcium saltpetre
1 000 kg/ha mixed fertilizer+300 kg/ha calcium saltpetre

	Marketable yield 1972—1974		Total yield kg/100 m²			In percent total yield		1st 2 wks' harvest in percent
	kg/100 m²	in percent	1972	1973	1974	Small size	Rotted	
In the open								
Unheated bed								
Unfertilized	121	(67)	129	231	185	9	24	90
500+150	106	(59)	152	220	171	9	32	88
1 000+300	92	(58)	126	179	169	11	31	88
mean	106	(61)	136	210	175	10	29	89
Heated bed								
Unfertilized	129	(61)	156	232	242	9	30	94
500+150	103	(57)	139	208	202	9	34	95
1 000+300	104	(58)	121	203	216	10	32	95
mean	112	(59)	139	214	220	9	32	95
In the open mean	109	(60)	137	212	198	9	31	92
Under netting								
Unheated bed								
Unfertilized	74	(63)	96	189	67	6	31	82
500+150	59	(62)	89	143	56	8	30	79
1 000+300	51	(57)	97	128	45	10	33	79
mean	61	(61)	94	153	56	8	31	80
Heated bed								
Unfertilized	71	(58)	95	117	92	11	31	94
500+150	51	(53)	82	131	77	12	35	94
1 000+300	47	(55)	80	117	58	15	30	93
mean	56	(55)	86	142	76	13	32	94
Under netting mean	59	(58)	90	148	66	10	32	87
LSD (95 %) growing place				39	67			
heating				no SD	14			
fertilization				20	23			

open, which led to an increased proportion of fruit blighted by grey mould. In 1974, when the season was exceptionally wet, the proportion of blighted fruit in the open was 38 %, and under the netting 47 %.

Unheated vs. heated plant heds

With the aid of the electric cables, it was possible to raise the temperature around the strawberry roots in the open by 17 %, and under the netting by 36 %, relative to the unheated soil. Except in the spring, the temperature was virtually identical in the unheated beds in the open and under the netting (Table 1).

The raising of the soil temperature did not however appear to have any effect on nutrient transfer from the soil to the plants. At the termination of the experiment, the nutrient content of the soil was virtually the same in the heated and unheated beds (Table 3). The potassium and magnesium content of the soil rose during the course of the experiment, but

Table 3. State of nutrients in the soil for the strawberry experiment, prior to fertilization in 1971 and following the termination of fertilization in 1974.
Soil: coarser fine sand
Variety: Sengana

	pH	Ca	K	P	B	Mn	Mg
	mg/l soil						
1971	6,3	1 411	211	30	0,5	2,3	196
1974							
Unheated bed							
Unfertilized	7,0	1 475	228	28	0,4	2,8	265
500+150	6,9	1 400	303	29	0,6	2,6	260
1 000+300	7,0	1 475	353	34	0,5	2,5	290
mean	7,0	1 450	295	30	0,5	2,6	272
Heated bed							
Unfertilized	7,0	1 650	248	31	0,6	1,9	333
500+150	7,0	1 475	300	35	0,5	2,5	300
1 000+300	6,9	1 450	365	32	0,5	2,5	315
mean	7,0	1 525	304	33	0,5	2,3	316
Optimum values	5,5 —6,5	2 500 —3 500	300 —350	50 —70	1,2 —2,2	5 —8	250

the rise was similar in scale in both the heated and unheated beds. In experiments carried out in the Netherlands, heating the soil was found to cause only minor variations in nutrient figures, apart from a higher nitrogen content recorded in the heated soil (Sondern 1975).

Nor was any effect of soil heating observable in the nutrient contents of the starwberry leaves and fruit; the differences in nutrient content and trace element content between plants grown in the heated and unheated beds were so small as to be insignificant (Table 4).

What was affected by heating the plant bed was the timing of flowering and harvest, which was advanced. In the heated beds, both in the open and under netting, flowering began 2—5 days earlier than in the unheated ones, and full flowering, similarly, occurred earlier. The yield harvestable during the first two weeks from the heated beds, both under netting and in the open, was higher than that from the unheated beds (Table 2).

The heating of the beds did not lead to increases in yield, with the exception of 1974 (Table 2), and did lead to a reduction in the proportion of the harvest which was marketable, since the proportion of fruit blighted with grey mould increased with the higher temperatures. The most deleterious effects on the yield of heating the soil were found under the netting. In addition to the blighted fruit, the proportion of undersize fruit also increased.

Fertilization

The quantities of fertilizer used in this experiment did not lead to higher yields. In each year of the experiment, the yield obtained (both overall and marketable) from the unfertilized control was higher, both in the open and under netting, than that from the fertilized treatments (Table 2). Neither of the fertilizer levels applied was particularly high, nor with the exception of the nitrogen did the quantities of fertilizer (N 78—156, P_2O_5 55—110, and K_2O 110—220 kg/ha) exceed the levels recommended for the strawberry (Leskinen 1977). Due either to the quantities applied of fertilizer, or to the effects of soil heating and netting, the increase

Table 4. Mean nutrient and trace element content in strawberry leaves and fruit, on unheated and on heated beds, 1972—1974.

Variety: Sengana

	N	K	P	Mg	B	Mn
	in dry matter					
	%	%	%	%	ppm	ppm
	Strawberry leaves					
Unheated bed						
Unfertilized	2,25	1,97	0,313	0,253	47,7	80,6
500+150	2,41	2,14	0,325	0,278	56,5	99,4
1 000+300	2,56	2,16	0,330	0,284	67,8	112,7
mean	2,40	2,09	0,322	0,271	58,3	97,5
Heated bed						
Unfertilized	2,31	1,86	0,318	0,259	45,9	79,1
500+150	2,34	1,93	0,322	0,291	56,6	98,3
1 000+300	2,48	2,05	0,335	0,300	62,6	100,2
mean	2,38	1,94	0,325	0,283	55,0	92,5
Optimum values (VANG-PETERSEN 1972)	2,25 —2,60	1,20 —1,50	0,220 —0,300	0,200 —0,300	20 —30	50 —100
	Strawberry fruit					
Unheated bed						
Unfertilized	1,28	2,30	0,352	0,149	18,8	28,1
500+150	1,53	2,44	0,374	0,161	17,9	29,0
1 000+300	1,70	2,62	0,400	0,174	19,0	34,0
mean	1,50	2,45	0,375	0,161	18,5	30,3
Heated bed						
Unfertilized	1,16	2,26	0,305	0,140	16,6	22,8
500+150	1,53	2,40	0,330	0,152	18,1	26,5
1 000+300	1,59	2,47	0,346	0,170	18,2	28,5
mean	1,43	2,37	0,327	0,154	17,6	25,9

in grey mould blight previously found with fertilization (SÄKÖ 1974) was not observed in this experiment.

Despite the continuation of fertilization over a period of four years, the nutrient content of the soil did not change greatly from what it had been prior to fertilization (Table 3). With increasing fertilization, the levels of potassium in the soil did rise to some extent, whereas in the unfertilized control the potassium content remained below the optimum.

Leaf and fruit analyses

Increasing fertilization led to corresponding increases in the amount of all nutrients and trace elements in the leaves and fruit (Table 4). The differences between the three levels of fertilization were small, but recurred as a similar trend each year.

In the year when they were planted, the leaves contained on average 2,54 % nitrogen by dry weight. The amount of nitrogen in the leaves was lower in the years with yield, ranging in the unfertilized control between 2,02—2,47 %. It has been estimated that the nitrogen content in the leaves for maximum yield in Sengana should not exceed 2,20 % but should also not fall below 1,60 % (SAKSHAUG 1971, YSTAAS 1971).

The quantity of potassium in the leaves of the plants previous to their first yield was on average 1,11 %, but rose in subsequent years, and displayed annual fluctuations. The lowest content recorded during the yield years in leaves of plants on the unfertilized control bed was 1,59 %, and the highest 2,34 %. The amount of potassium was thus in excess of the estimated optimum throughout the experiment, even on the unfertilized control.

The boron content in the leaves declined during the course of the experiment. The leaves of plants on the unfertilized control contined on average in 1973 60,0 ppm boron by dry weight, and in 1974 on average 35,0 ppm; the corresponding figures for the treatments with maximum fertilization were 86,8 ppm and 46,3 ppm. The boron content of the leaves may vary between different soils (LJONES 1962), nor is the effect of leaf boron content on yield completely clear. BJURMAN (1974) suggests that boron content in excess of 50 ppm in the strawberry's leaves will have the effect of diminishing the yield.

The phosphorus content in the leaves remained steady troughout the experiment, on average slightly above the estimated optimum, while the quantities of manganese in the leaves remained within the optimum range found for Sengana (ANON. 1972).

DISCUSSION

The experiment was intended to investigate the micro climatical conditions created by a protective netting structure, and the implications of these for strawberry cultivation. The results indicate that the conditions obtaining under the netting, in terms of light and temperature, e.g. the lower mean temperatures in the early part of the season, do not further growth, flowering, or yield in the strawberry, and that the conditions in the open are preferable. Whereas, under Finnish conditions, cultivation in plastic-clad greenhouses can advance the flowering and the harvest by two weeks (SÄKÖ 1975), this was not found to be possible with the netting. The Sengana began flowering a mere couple of days earlier under the netting than in the open, and the fruit failed to ripen earlier than open fruit. With a variety as susceptible to grey mould as Sengana is, the conditions under the netting (especially in poor seasons) merely increase the danger of blight occurring.

The effect of soil heating on growth and yield in the strawberry has been studied in the Netherlands, in early strawberry cultivation. In spring conditions, where daylight, the air temperature, and the level of moisture in the soil àre all adequate, the incidence of growth can be advanced by raising the temperature of the soil. With the strawberries (Glasa variety) in a plastic tunnel, raising the soil temperature enabled a harvest ten days in advance of that on unheated soil (SONDERN 1975). The present investigation indicates that in Finnish conditions, soil heating can advance the flowering of the strawberry in the open by several days, depending on the weather, and a similar advance can be achieved in the mature harvest. Conceivably early strawberry varieties may react to soil heating more than the late variety, Sengana used here. On the other hand, the earlier the strawberry's flowering occurs, the greater danger there is of damage from spring frosts, in which many of the flowers may be lost. In a dry early summer, soil heating promotes the drying of the soil, whereas in wet weather it assists the development of grey mould blight.

The results on the effect of fertilization on the yield were similar to those obtained previously both in Finland and elsewhere (BJURMAN 1974, SÄKÖ 1974, et al.); increasing the amount of fertilizer did not lead to any increase in yield in this case either, and the largest yield was harvested from the unfertilized control. This illustrates the low need for fertilizer in the Sengana variety, with its luxuriant growth. It has been found in Denmark that Sengana is usually over-fertilized with nitrogen and potassium fertilizers, leading to a reduction in yield (ANON. 1972). Tests carried out in Sweden concerning nitrogen and boron failed to provide any explanation of the fluctuations in yield occurring with different levels of fertilization (BJURMAN 1974). The overall indication of a number of fertilization experiments, therefore, suggets that maximization of the overall and marketable yield will not be achieved merely by increasing the fertilizer administred to the strawberry in cases where the other factors affecting strawberry growth are unfavourable. In the present experiment, Sengana provided a weaker yield under protective netting than in the open. This may have been due to the low light levels and temperatures at the end of the season, when the buds for the following season are first formed. Even if fertilization had no direct effect on the yield, therefore, by encouraging luxuriant growth it creates a deterioration in light conditions within the vegetation and may affect the flowering in the following year.

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SELOSTUS

Maan lämpötilan vaikutus mansikan ravinteiden ottoon, kasvuun ja satoon

EEVA LAURINEN ja JAAKKO SÄKÖ

Maatalouden tutkimuskeskus

Puutarhantutkimuslaitoksessa Piikkiössä tutkittiin vuosina 1971—1974 lannoituksen ja maan lämpötilan vaikutusta mansikan ravinteiden ottoon, kasvuun ja satoon. Koe suoritettiin sekä avomaalla että tiheäsilmäisestä keinokuidusta rakennetussa verkkohuoneessa. Lannoittamattoman koejäsenen lisäksi käytettiin kahta lannoitustasoa. Kevätlannoituksena oli puutarhan Y-lannos, jonka pääravinnesisältö oli N 55 ja 110 kg/ha, P_2O_5 55 ja 110 kg/ha sekä K_2O 110 ja 220 kg/ha. Lisälannoituksena oli sadonkorjuun jälkeen kalkkisalpietari, ravinnesisällöltään N 23,3 ja 46,6 kg/ha. Maata lämmitettiin mansikan juuriston ympärille noin 10 cm syvyyteen upotetuilla sähkökaapeleilla kasvukauden aikana.

Käytetyillä lannoituksilla ei mansikalle saatu sadonlisäystä. Lannoittamatta jätetystä kasvustosta saatiin suurin sato. Kaapelilämmityksellä voitiin maan lämpötilaa kohottaa kasvukauden aikana keskimäärin 2—4 °C, verkkohuoneessa hieman enemmän kuin avomaalla. Lämmitys aikaisti kukintaa ja satoa muutamalla päivällä, mutta ei vaikuttanut sadon määrään. Sen sijaan lämmitys heikensi sadon laatua erikoisesti verkkohuoneen olosuhteissa. Harmaahomeen saastuttamien sekä pienten marjojen osuus sadossa lisääntyi. Maaperän kohonnut lämpötila ei vaikuttanut ravinteiden siirtymiseen maasta kasviin eikä myöskään lehtien ja marjojen sisältämiin ravinnemääriin.

Verkkohuoneeseen muodostuneet lämpö-, valaistus- ja kosteusolosuhteet eivät olleet mansikalle edullisia. Verkkohuoneen kasvustosta saatiin satoa keskimäärin vain 56 % avomaan sadosta.

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Seria PHYTOPATHOLOGIA N. 71 — Sarja KASVITAUDIT n:o 71

STUDIES ON POTATO GANGRENE IN FINLAND

ESKO SEPPÄNEN

SEPPÄNEN, E. 1980. **Studies on potato gangrene in Finland.** Ann. Agric. Fenn. 19: 173—179. (Agric. Res. Centre, Inst. Pl. Path., SF—01300 Vantaa 30, Finland.)

Two types (grey and brown) of *Phoma exigua* Desm. var. *exigua* and one type (yellow) of *Phoma exigua* Desm. var. *foveata* (Foister) Boerema were isolated and identified from tubers with gangrene symptoms. Some trials were carried out on the pathogenicity and optimum growth conditions of the species. A temperature of 12 °C was more favourable for the growth of var. *foveata* in the tubers of Bintje than the other temperatures studied (6, 18, 24 and 30 °C). The optimum temperature for the growth of var. *exigua* seemed to be lower. Three preliminary experiments were carried out on varietal resistance. Noteworthy cortical resistance to var. *foveata* was established in cultivars Hankkijan Tuomas, Jaakko and Sieglinde. According to these results the resistance of the cultivars to var. *foveata* does not correlate with their resistance to var. *exigua*.

Index words: Gangrene, growth conditions, varietal resistance.

INTRODUCTION

The potato gangrene problem in Finland is fairly new. The disease was first found only at the end of the 1960s in Bintje tubers originating from imported stocks (SEPPÄNEN 1972). The problem has grown since 1975, when large amounts of seed potatoes were imported from a number of western European countries. The disease has spread to all parts of the country via the seed stocks, and is now, with Fusarium dry rot, one of the main problems in Finnish potato production (SEPPÄNEN 1977). The present paper deals with studies on identification, pathogenicity, growth under different conditions and varietal resistance of the *Phoma* species carried out in 1975—80.

Material. In connection with the seed potato imports of 1975, a total of 73 tuber samples were analyzed to investigate the occurrence of potato gangrene and Fusarium dry rot. During the subsequent years about 300 tuber samples were collected from different parts of the country, partly from stocks originating from the imported stocks and partly from farms having no contact with the imported stocks. No pre-planned schedule was used in the collection of the samples, and some were received from farmers who sent tuber samples with requests for information about the »new diseases».

Isolation and identification. The pathogens were isolated using conventional methods. Tubers with gangrene lesions were cut into pieces, disinfected and placed in Petri dishes on moist filter paper at room temperature. Within a few days sufficient fungi had grown for isolation. The isolates were grown on potato dextrose agar or malt agar. Each isolate identified was raised from a single hypha of the fungus. The identifications of *Phoma* species employed the NH_3 test and the thiophanate-methyl test developed by Tichelaar (1974). Some of the identifications were confirmed by the chrysophanol chromatograph test developed by Mosch and Mooi (1975).

Pathogenicity tests. The pathogenicity of the species or separate isolates of them, as well as their growth rates under different environmental conditions, were studied using an adaptation of the method of Langton (1971). At the mid-point between the heel and rose end of washed and dried tubers a wound 5 mm in diameter and 2 mm deep was made with a cork borer. The mixture of pure cultures of the fungi including the rest of the agar was used as inoculum. The age of the colonies varied from one to two months. The wounds were filled with inoculum and left uncovered. The method was equally effective when compared with that of Langton. A slightly poorer effect was obtained when a pycnospore suspension was used as inoculum. The number of tubers used for each treatment was 10, and the test was repeated once or twice. Tuber infection was scored after 20 days incubation. The tubers were cut in two longitudinally through the infection locus, and the growth of fungus at the cut tuber surface, i.e. the radial growth in the peel (and beneath it if greater) and the deepest axial growth were measured. Generally only the average figures for radial and axial growth are presented.

All these studies were carried out with Bintje, well-known as a cultivar which is very susceptible to gangrene. The isolates used had been recently grown in Bintje. The isolate of *Phoma e.* var. *foveata* used in these trials had been isolated from a Sientje stock imported from France in 1975, and that of var. *exigua* (brown) originated in a native stock of Pito.

Tests on varietal resistance. The experiments were carried out with tubers of the cultivars grown, harvested, stored and infected in a similar manner. The inoculation and scoring methods were the same as those used in the pathogenicity experiments. However, with var. *foveata* an additional test was performed with medullary inoculation to a depth of 10 mm. These experiments involved 20 tubers of each cultivar with 3 replicates, apart from the test with var. *exigua* in which there were only 3 × 10 tubers. The incubation conditions were slightly different in each test but always almost optimal for the fungi.

All the results were analyzed using variance analysis and the LSD values were calculated with Tukey-Hartley tables.

***Phoma* species.** About 120 isolates of *Phoma* were isolated and identified from tubers with different gangrene symptoms. Most could be identified correctly on the basis of the colour of each isolate grown as a pure culture on potato dextrose agar: the grey isolates belonging to *Phoma exigua* var. *exigua* and the yellow ones to *P. exigua* var. *foveata*. The thiophanate-methyl and chrysophanol chromatograhp tests confirmed the results. Apart from the grey and yellow isolates there were some with brown mycelia which proved to belong to var. *exigua*. When young these had a greater resemblance to var. *foveata*, but later the cultures turned dark brown and they lacked the ability to produce the yellow pigment characteristic of var. *foveata*. A weak ability to form pycnidia on agar is peculiar to these brown isolates. In 1975—76 the majority of isolates belonged to var. *exigua*, and in 1977—80 to var. *foveata*.

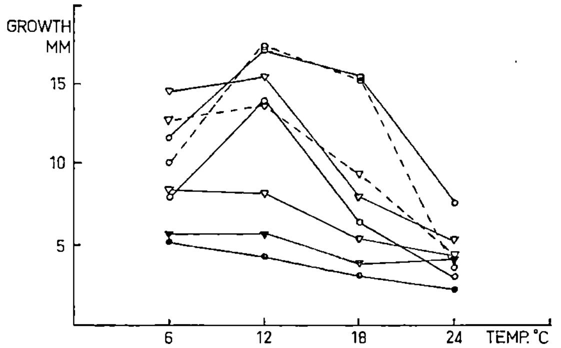

Fig. 1. Radial and axial growth of *Phoma exigua* var. *foveata* and *P. exigua* var. *exigua* under different environmental conditions in Bintje cultivar. The tubers were inoculated to 2mm and scored 20 days after inoculation.

○	radial growth of var. *foveata*
▽	axial » » »
●	radial » » *exigua*
▼	axial » » »
——	RH of 95 ± 5 %
- - -	» of 50 ± 10 »

Pathogenicity. Some preliminary experiments on the pathogenicity of the species were carried out in 1976—77. Five isolates of var. *foveata* and three of var. *exigua* were compared without selection, and the means of the radial and axial growth were as follows:

var. *foveata* radial growth 11,8 mm axial growth 9,0 mm
var. *exigua* radial growth 4,3 mm axial growth 5,4 mm

The pathogenicity of var. *foveata* isolates was more uniform and higher than that of the isolates of var. *exigua*.

Optimum growth conditions. The influence of environmental conditions (temperature and relative humidity) on the growth of the fungi was studied. The temperatures used were 6, 12 18, 24 and 30 °C and the RH values were 50±, 10 % and 95 ± 5 % (at 12 °C also 70 ± 10 %). The lower RH values were very difficult to regulate at the different temperatures and varied by as much as 10 per cent from the values required. The influence of RH appeared to be minor compared with temperature, so RH variation had little effect on the results obtained.

The results (Fig. 1 and Table 1) show that the optimum growth temperature for var. *foveata* was 10 to 12 °C. The axial growth of the fungus was equal at 6 and 12 °C, but the radial growth was significantly greater at 12 °C. The optimum temperature for the growth of var. *exigua* seemed to be lower, 6 rather than 12 °C. The maximum growth of var. *foveata* was 1 mm per day, and that of var. *exigua* less than half of that. At 18 °C, in the experiment carried out in October, most tubers were capable of arresting the advance of var. *foveata*, but in May the growth was only delayed by the reaction of the tubers. At 24 °C infections were only rarely progressive and at 30 °C no infection took place. Bintje proved to be fairly resistant to this isolate of var. *exigua* and as such hardly suitable for the determination of growth rate or optimum growth conditions. The relative

Table 1. Growth of *Phoma exigua* var. *foveata* and *P. exigua* var. *exigua* in Bintje cultivar under different environmental conditions. No growth at 30°C.

Temperature/RH			Growth (mm) in 20 days		
			Phoma exigua var. *foveata*		*P. e.* var. *exigua*
			May 1979	October 1979	April 1980
6±1°C	50±10 %		11,5	—	—
6	95	5	13,0	8,1	5,4
12	50	10	15,5	—	—
12	70	10	15,9	—	5,9
12	95	5	16,3	11,1	5,1
18	50	10	12,3	—	—
18	95	5	11,7	5,9	3,4
24	50	10	3,9	—	—
24	95	5	6,4	3,6	3,6
	F		49,21***	181,28***	46,22***
	LSD[1] %		2,5	1,2	0,7

humidity had only very slight or no influence on the growth of the fungi.

The results of temperature and RH influence on the growth of the fungi in potato tubers are rather similar to those obtained by KRANZ (1958), but differ slightly from those of MALCOLMSON (1959) who found the optimum temperature to be 5 °C. The differences in results may be partly explained by the different cultivar used, as, according to the author's experience, the fungi does not grow similarly in all cultivars. Bintje has very weak or no cortical resistance to var. *foveata* while the medulla seems to be more resistant. Converse results were obtained with most cultivars tested. The results with var. *exigua* are too few for conclusions to be drawn.

Varietal resistance. These tests on varietal resistance were brief, limited to tubers of one season and one growth site, and to a single incubation period. The results, however, were fairly similar and so probably do not provide a completely false picture of the situation. In any case, they must be regarded as preliminary.

The resistance of cultivars varies greatly. Although these experiments were carried out under almost optimum conditions for the fungi, many cultivars fairly effectively prevented the advance of the pathogens. The differences in resistance between cultivars were greater when isolates were inoculated into the cortical tissue (2 mm), compared with those with medullary inoculations. In practice cortical resistance is of the major importance and so only cortical inoculation was performed in the experiment with var. *exigua*. Incubation time as well as the depth of inoculation had a certain influence on the results as the fungi had different growth rates in cortical and medullary tissues. Therefore, there were some difficulties in presenting results unambiguously and in the ranking of cultivars for resistance. We have used the average of radial and axial growth.

In our tests with var. *foveata*, Bintje, Hankkijan Timo, Jo 0701, Ostara, Provita, Record, Sirtema and Stina proved to be very susceptible (Table 2). The Finnish cultivars Hankkijan Tuomas and Jaakko, and the old German

Table 2. Results of the preliminary tests on varietal resistance to *Phoma exigua* var. *foveata* and *P. exigua* var. *exigua*.

Cultivar	*P. exigua* v. *foveata*		*P. exigua* v. *exigua*
Incubated 20 days at temp. °C/RH % Inoculated to Test performed in	12±1/80±10 2 mm November	7±1/80±10 10 mm February	10±1/75±10 2 mm April
Jaakko	3,3	9,4	6,3
Hankkijan Tuomas	3,4	8,9	7,3
Sieglinde	4,1	9,5	5,6
Veto	4,7	11,0	7,8
Sanna	4,7	11,8	7,7
Olympia	5,4	10,6	7,4
Sabina	5,7	11,2	7,2
Saturna	5,8	9,6	6,4
Pito	6,1	11,7	7,0
Hankkijan Timo	6,8	13,9	7,1
Provita	6,9	13,0	6,3
Record	7,1	13,5	4,9
Stina	7,6	14,3	7,6
Sirtema	8,3	13,0	8,4
Ostara	9,1	13,8	—
Jo 0701	9,1	13,4	—
Bintje	9,3	11,8	5,4
F	95,30***	22,51***	117,65***
LSD_5 %	0,6	1,1	0,7

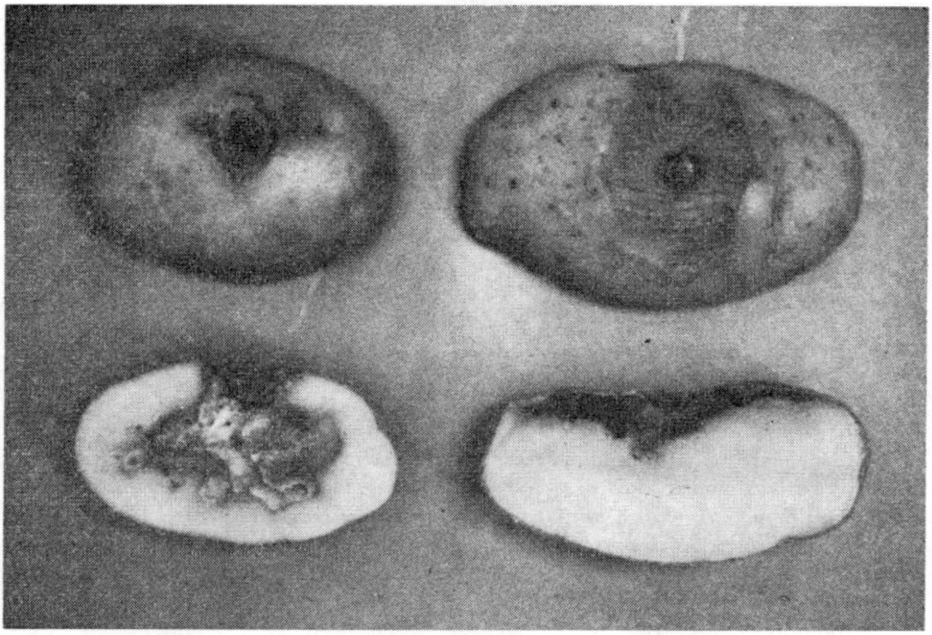

Fig. 2. Contrasting growths of *Phoma exigua* var. *foveata* in tubers of Jo 0701 and Bintje 6 weeks after cortical inoculation.

cultivar Sieglinde appeared to be the most resistant. The differences between the resistant cultivars and the susceptible ones were less when inoculation was to a depth of 10 mm because the resistance of most cultivars was limited to the cortical tissue of the tubers. The resistance of these cultivars to var. *exigua* does not seem to be correlated with that to var. *foveata*. Bintje and Record, being among the most susceptible to var. *foveata*, proved to be the most resistant to var. *exigua*. Var. *exigua* was a weaker parasite and the differences in resistance between cultivars were smaller compared with var. *foveata*. Further trials are needed to confirm the results obtained.

Difference in resistance between cortical and medullary tissues is not a new finding. Jellis (1975) and Pietkiewich and Jellis (1975) have established this phenomenon and its importance. In the present results the differences are more striking; perhaps an extreme example of this is my finding with tubers of Bintje and the breeders selection Jo 0701. In the test carried out in November with var. *foveata* 10 extra tubers of each cultivar were scored 6 weeks after inoculation. These two very susceptible cultivars behaved conversely; in Bintje the fungus grew mainly in the cortex and in Jo 0701 apically through the medulla (Fig. 2), while in most cultivars the fungus advanced nearly equally in both directions. The present results are similar to the observation of Jellis (1975) that differences in resistance are smaller following inoculation to 10 mm than to 2 mm. Concerning the behaviour of resistant cultivars Jellis concluded that radial growth exceeded axial growth and that the vascular cylinder acts as a barrier. According to my short experience the behaviour of resistant cultivars was precisely the reverse; i.e. apical growth exceeded radial growth. The importance of the vascular cylinder is scarcely restricted to resistant cultivars but Bintje, for example, may have some such resistance.

These experiments included some cultivars studied by Bång (1972, 1976) and Nielsen (1977), whose results were fairly similar. In the present tests, however, Record and Stina proved to be more susceptible compared with Bintje and Saturna than in the tests made by these authors. The higher resistance of Hankkijan Tuomas, Jaakko, Sieglinde and even Saturna may be of practical importance and further studies should be performed under more practical conditions.

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SELOSTUS

Tutkimuksia phomamädän aiheuttajista, niiden patogeenisuudesta ja elinvaatimuksista sekä lajikekestävyydestä

Esko Seppänen

Maatalouden tutkimuskeskus

Tutkimus perustuu kasvitautien tutkimuslaitokselle v. 1975—80 koottuihin perunanäytteisiin, joista 73 otettiin suoraan tuontisiemeneristä keväällä 1975 ja noin 300 näytettä v. 1975—80 viljelijöiltä maan eri puolilta. *Phoma*-isolaatteja kertyi kaikkiaan noin 120, joista määritettiin 2 tyyppiä (harmaa ja ruskea) *Phoma exigua* Desm. var. *exigua* ja yksi *Phoma exigua* Desm. var. *foveata* (Foister) Boerema. Vuosina 1975—76 eristetyissä oli var. *exigua* vallitseva, myöhempinä vuosina var. *foveata*. Viime mainittu osoittautui patogeenisemmaksi.

Sienten kasvua tutkittiin 5 lämpötilassa (6, 12, 18, 24 ja 30 °C) ja erilaisissa kosteusoloissa. Koelajikkeena oli Bintje. Optimilämpötilaksi var. *foveata*lla todettiin 10—12 °C ja vielä 24 °C:ssa sieni pystyi tartuttamaan Bintjen, mutta ei enää 30 °C:ssa. Var. *exiguan* optimi näyttää olevan alhaisempi. Kosteusolojen merkitys on näiden kokeiden mukaan vähäinen.

Lajikkeiden kestävyystestissä selvitettiin sienen kasvua eri lajikkeissa. Koska lajikkeet tartutettiin tekemällä haava mukulaan, eivät tulokset osoita lajikkeen koko taudinkestävyyttä vaan ainoastaan sienenkestävyyttä. Kokeita on pidettävä alustavina, mutta on ilmeistä, että lajikkeistamme ainakin Hankkijan Tuomas, Jaakko ja Siikli omaavat käytännön kannalta merkittävää kestävyyttä var. *foveataa* vastaan, kun taas Rekord, Bintje ja Siikli olivat kestävimmät var. *exiguaa* vastaan.

ANNALES AGRICULTURAE FENNIAE, VOL. 19: 180—185 (1980)
Seria ANIMALIA DOMESTICA N. 53 — Sarja KOTIELÄIMET n:o 53

OF THE BONE MINERAL CONTENTS OF YOUNG DAIRY BEEF CATTLE

VAPPU KOSSILA and LEA HUIDA

KOSSILA, V. & HUIDA, L. 1980. **Of the bone mineral contents of young dairy beef cattle.** Ann. Agric. Fenn. 19: 180—185. (Argic. Res. Centre, Inst. Anim. Husb., SF—31600 Jokioinen, Finland.)

Bone samples were collected from young dairy beef animals at slaughter. The animals had been raised in two different locations, at the North-Pohjanmaa Experimental station, Ruukki, and in Jokioinen. Bones were analyzed for fat, ash content of dry matter and calcium, magnesium, phosphorus, sodium, potassium, zinc, copper and manganese contents of ash. Metacarpus contained significantly less fat and significantly more ash than rib or 4th carpal bone. Ca, P, Na Mn contents of the different bones were similar. Ribs contained more Mg, K, Cu and Zn than other bones.

Animals raised in Ruukki had more Ca but less P in their ribs than animals raised in Jokioinen. The bones of the animals from Ruukki had significantly less Mg but more K and Cu than animals from Jokioinen. Mineral content of bones can evidently be influenced by feeding.

Index words: Cattle, bones, minerals.

INTRODUCTION

Bone ash contains about 36,5 % calcium (Ca), 17,0 % phosphorus (P) and 0,8 % magnesium (Mg). A cow's skeleton contains 0,14 g potassium (K) and 6,0 g sodium (Na) per kg dry matter (DM). The skeleton of a milking cow contains 3,4 ppm manganese (Mn) and that of a 140 day-old calf contains 3,2 ppm. The cow's ribs contain 2,5 ppm copper (Cu). In man, the Cu content of the ribs decreases significantly with age; a child of 3—4 years has 16 ppm Cu, a teenager 7 ppm and an adult has only 5,5 ppm Cu. The zinc content of the ribs is about 47 ppm (HENNIG 1972). The carpal bone of a milking cow contains 55 ppm Zn, the rib 47 ppm and the vertebra 22 ppm Zn in DM (HAHN 1971). The Zn content of a goat kid femur was 112 ppm when the diet of the mother contained 100 ppm Zn but was 84 ppm when the diet of the mother contained 7 ppm Zn (HENNIG 1972).

The incorporation of minerals into the bovine skeleton is very intensive during the few first months of life. Young dairy calves fed only with oat meal (1,5 or 4,5 kg/day/calf) and grass silage ad libitum developed symptoms of fatal mineral deficiency while controls supplemented with mineral salt mixture remained healthy. Deficiency symptoms were broken femurs, tetany associated with significantly lowered serum Ca and Mg even P levels, and significant elevation of serum alkaline phosphatase activity (Kossila et al. 1977). Recovery was complete when mineral salt mixture was introduced into the diet. However, five animals had to be slaughtered because of broken bones or tetany. Animals in the control group had an average of about 10 kg heavier carcasses when they were slaughtered at about 436 days old. Johnsson et al. (1977) demonstrated an increase in the bone ash content of fattening bulls with increasing dietary Ca supplement on a hay-concentrate diet. Moreover, Ca supplement gave a better growth rate at a higher than at a lower level. These two studies indicate that in Finland and Sweden the Ca content of some cattle feeds can be too low to satisfy the Ca requirements of rapidly growing calves. Copper deficiency in the diet causes bone deformities and fractures while bone ash, Ca and P remain normal. In Zn deficiency, bone Zn is reduced, the long bones of the limbs do not grow properly, bones become thick, bone degeneration may be seen, and the activity of several enzymes such as alkaline phosphatase and lactic acid dehydrogenase is depressed. Subnormal alkaline phosphatase activity has also been found in the serum of Mn-deficient lambs. Bone Mn content is not always reduced in cases showing Mn deficiency (Underwood 1971). Calves from Mn-deficient dams may have twisted legs, enlarged joints, more brittle humeri etc. compared to calves born to non-deficient dams (Roy 1970). Sufficient amounts of Zn, Cu and Mn are thus needed in order to maintain normal bone formation. Agricultural Research Centre has two Experimental Stations at which beef cattle experiments are carried out. One of these is near Oulu in Ruukki and the other is at Lintupaju in Jokioinen. Earlier studies concerning the mineral contents of hay, silage and grass indicated significant differences between the northern and southern parts of Finland (Kossila et al. 1973, Kähäri and Paasikallio 1978, Ettala and Kossila 1979). Furthermore, perhaps due to mineral imbalance, some bone troubles and retarded growth have been recorded in young cattle kept in Ruukki. Calves in Jokioinen have generally been in better condition and have grown faster than those in Ruukki. The purpose of this study was to find out whether the calves in Jokioinen had a bone composition different from those kept in Ruukki and whether the possible differences in the bone composition could be explained on the basis of differences in the feeding.

MATERIAL AND METHODS

Three bone samples were taken from 32 dairy beef bulls raised at Lintupaju in Jokioinen and two bone samples were collected from 32 beef bulls and heifers raised at the North Pohjanmaa Experimental Station, Ruukki, during June-August, 1976. Animals raised at Lintupaju were either Ayrshire or Ayrshire × Herefords crosses. Animals in Ruukki were Charolais × Ayrshire or Friesian × Ayrshire. Some information concerning the animals is given in Table 1.

One bone sample (0,5—1,0 cm) was taken from the distal part of the 7th left rib. The second sample (0,5 cm) was taken from the metacarpus of the left foreleg (a circular piece of bone was removed with a saw from about six centimeters below the knee joint). The third sample was the entire 4th carpal bone of the left foreleg, and these were collected only from the Jokioinen animals.

Table 1. Average age, live weight, carcass weight, gain and feed consumption of the animals studied.

Item	Lintupaju 004	Ruukki 014
Days in the experiment	297	355
Age at slaughter (days)	364	436
Live weight at slaughter (kg)	362	371
Carcass weight (kg)	175	186
Gain (g/day)	1 019	967
FU/kg gain	4,56	4,22
Feed consumption (kg/day)		
Roughage *)	1,51	11,96
Concentrates **)	4,34	2,57
DM intake (kg/day/animal)	5,02	4,52
DM intake/kg gain	4,93	4,67

*) Hay was fed at Lintupaju and grass silage in Ruukki.
**) Oats + molasses beet pulp + some nonprotein nitrogen at Lintupaju, oatmeal in Ruukki.

The same mineral mixture was used in both places (Seleeni—Terki).

Bones were kept deep-frozen until analyzed. Surrounding muscles, tendons, etc. were carefully removed from the bones for a short time in boiling water. The bones were then crushed and dried overnight at 105 °C. The bone pieces were then placed into a linen bag and extracted with ether for 6 hours in order to remove fat. Dried defatted bones were weighed and ashed in an oven. Ashing was started at 250 °C and the temperature was gradually increased up to 520 °C, at which the bones remained overnight. The temperature was finally raised up to 800 °C for 1 h. Ash was dissolved in conc. HCl and kept over a boiling waterbath for 1 h. The HCl was evaporated and the ash was redissolved in HCl and filtered. Dilutions for estimation of the elements were prepared from the filtrate. Ca, Mg, K, Na, Cu, Zn and Mn were estimated using an atomic absorption technique. Phosphorus was determined using an official method (Official Methods 1965).

RESULTS AND DISCUSSION

The average fat content of the bone DM and the ash content of the fat-free bones are shown in Table 2. The metacarpus sample contained significantly less fat but significantly more ash than the rib or 4th carpal bone. Differences in bone fat or ash contents between Ruukki and Jokioinen were not significant.

The Ca and P contents of bone ash were quite similar in different bones (Table 3). Ca in the rib ash from Ruukki's animals was somewhat higher, but P was lower than the respective values of the Jokioinen animals. The Ca/P ratio of the bone ash of the animals from Ruukki was a little higher than the animals from Jokioinen.

Table 2. Fat and ash content of ribs, metacarpal and 4 th carpal bones

	Lintupaju		Ruukki		
	$\bar{x}$	range	$\bar{x}$	range	
Fat, % in bone DM					
Rib	15,20	6,44—31,61[a]	10,77	6,29—34,13[a]	NS
Metacarpus	1,71	0,12—12,81[b]	0,96	0,11—10,13[b]	NS
4th carpal bone	13,99	7,80—24,03[a]	—	—	
Ash, % in fat-free bone DM					
Rib	59,63	57,70—61,35[b]	60,11	56,97—62,58[b]	NS
Metacarpus	66,62	63,72—67,70[a]	65,77	63,12—67,24[a]	NS
4th carpal bone	59,26	58,39—60,86[b]	—	—	

a > b = P < 0,001 (vertical); DM = dry matter, $\bar{x}$ = mean value, NS = nonsignificant (horizontal).

Table 3. Calcium and phosphorus contents and Ca/P ratio of the ribs, metacarpal and the 4th carpal bones.

	Lintupaju		Ruukki		
	x̄	range	x̄	range	
Ca, % in bone ash					
Rib	38,96	36,83—40,30	40,32	38,53—43,17	*
Metacarpus	39,41	37,64—40,90	38,63	37,56—40,37	NS
4th carpal bone	38,59	37,02—39,51	—	—	
P, % in bone ash					
Rib	15,78	14,36—18,07	15,08	12,63—16,50	*
Metacarpus	15,31	14,73—16,76	14,65	12,77—16,25	NS
4th carpal bone	15,94	14,43—17,29	—	—	
Ca/P ratio in the bone ash					
Rib	2,57	—	2,67	—	
Metacarpus	2,57	—	2,64	—	
4th carpal bone	2,42	—	—	—	

* $P < 0{,}05$ (horizontal)

The Mg and K contents of the investigated bone types differed significantly from each other (Table 4). Ribs contained more Mg and K than the other bones. Animals from Ruukki had significantly less Mg and somewhat more K in their bones than animals from Jokioinen. Only animals from Jokioinen were included in the Na determinations. The Na content of all bone types studied was similar (Table 4).

The Zn and Cu contents were influenced by the bone type (Table 5). Ribs contained more Cu and Zn than other bones. The Mn content was similar in all bones. Animals raised in Ruukki had significantly more Cu in their bones than those raised in Jokioinen. Ruukki is located in a Cu-deficient area, but, Cu-containing fertilizers have been applied on the fields of Ruukki.

The mineral contents of the bones in this study agree more or less with those presented earlier in the literature. Bone ash mineral content can obviously be influenced to some extent by

Table 4. Magnesium, potassium and sodium contents of the ribs, metacarpal and 4th carpal bones

	Lintupaju		Ruukki		
	x̄	range	x̄	range	
Mg, % in bone ash					
Rib	0,80	0,70—0,87[e]	0,62	0,50—0,74[e]	***
Metacarpus	0,70	0,64—0,73[f]	0,53	0,42—0,64[f]	***
4th carpal bone	0,72	0,66—0,78[f]	—	—	
K, % in bone ash					
Rib	0,072	0 048—0,118[a]	0,082	0,048—0,152[a]	NS
Metacarpus	0,017	0,013—0,019[bf]	0,022	0,014—0,034[b]	NS
4th carpal bone	0,023	0,016—0,034[be]	—	—	
Na, % in bone ash					
Rib	0,80	0,68—1,02	—	—	
Metacarpus	0,75	0,67—0,88	—	—	
4th carpal bone	0,75	0,60—0,87	—	—	

*** $P < 0{,}001$ (horizontal). a > b = $P < 0{,}001$, e > f = $P < 0{,}05$ (vertical).

Table 5. Copper, zinc and manganese contents of the ribs, metacarpal and 4th carpal bones.

	Lintupaju		Ruukki		
	x̄	range	x̄	range	
Cu, % in bone ash					
Rib	0,006	0,004—0,014[c]	0,024	0,014—0,041[c]	***
Metacarpus	0,005	0,004—0,005	0,009	0,006—0,018[d]	***
4th carpal bone	0,004	0,004—0,005[f]	—	—	
Zn, % in bone ash					
Rib	0,16	0,11—0,20[c]	0,12	0,10—0,17[e]	NS
Metacarpus	0,10	0,08—0,13[d]	0,10	0,07—0,13[f]	NS
4th carpal bone	0,13	0,11—0,15	—	—	
Mn, % in bone ash					
Rib	0,007	0,004—0,011	0,006	0,005—0,009	NS
Metacarpus	0,007	0,005—0,008	0,006	0,005—0,007	NS
4th carpal bone	0,007	0,006—0,008	—	—	

*** $P < 0,001$ (horizontal). $e > f = P < 0,05$, $c > d = P < 0,01$ (vertical).

feeding. Four animals which were raised in Ruukki and had either broken bones or tetany were included in the bone study. The bone composition of sick animals was, however, similar to that of healthy ones.

In Jokioinen, three supplements (urea, urea-phosphate and soya protein adjusted on nitrogen basis) were compared in the feeding of the calves during the three first months of the experiment. Calves which had received urea or ureaphosphate had a little less K in their ribs and 4th carpal bones than calves supplemented with soya protein or control calves.

In Ruukki, calves fed with a lower concentrate level had more P (15,27, 15,21 %) and K (0,086, 0,025 %) in their ribs and metacarpus, respectively, compared with those which received a higher concentrate level (14,54, 14,20 % P and 0,069, 0,018 % K, respectively). The low concentrate group consumed more grass silage. Silage contained more K than oatmeal. It seems that K may accumulate in the bones to a greater extent at a higher dietary K level than at a lower dietary level. In Ruukki, silage DM contained about the same amount of P as oat DM. It is possible that silage P is more easily available to calves than oatmeal P.

The differences in bone mineral composition observed between the Jokioinen and Ruukki areas may be explained by the type of diet; more concentrate and mineral-poor hay was used in Jokioinen, while silage was fed to the animals in Ruukki. Silage usually contains more minerals than hay. Moreover, animal material was different in the two locations.

This study and the earlier one (Kossila et al. 1977) indicate that mineral deficiencies are more easily explained on the basis of blood mineral values than on the basis of bone mineral composition. Hair mineral composition failed to reveal severe mineral imbalance in growing cattle.

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SELOSTUS

Luiden kivennäispitoisuuksista nuorilla lihanaudoilla

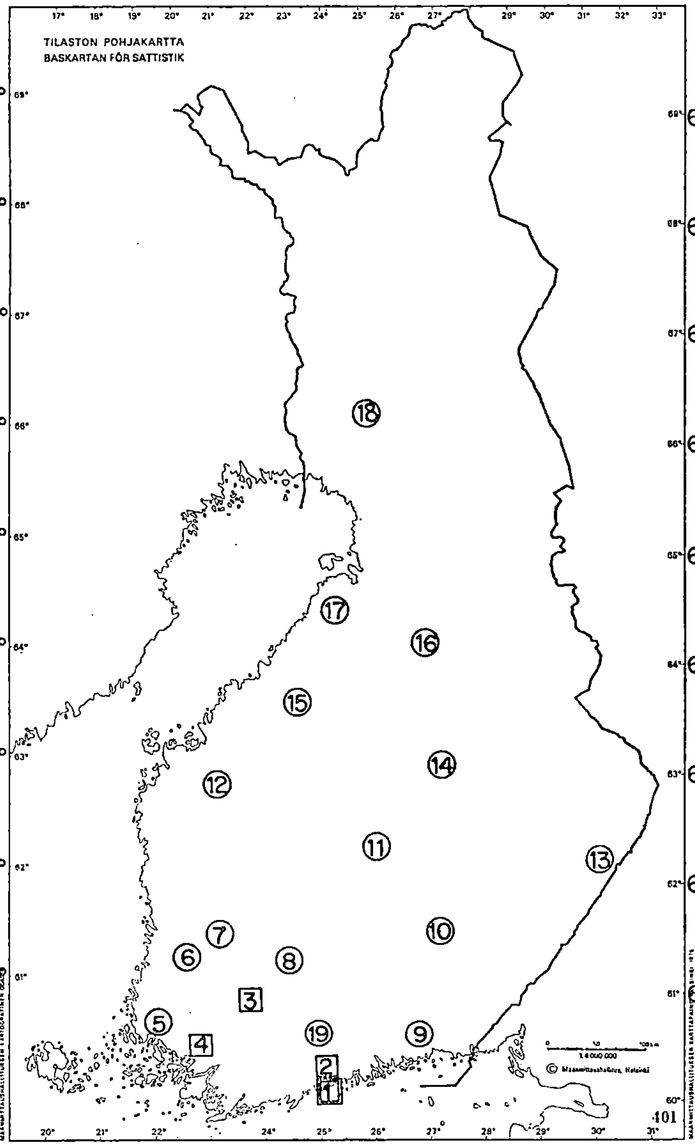
VAPPU KOSSILA ja LEA HUIDA

Maatalouden tutkimuskeskus

Pohjois-Pohjanmaan koeasemalla (Ruukki) ja Jokioisten Lintupajussa kasvatetuista lihavasikoista kerättiin teurastuksen yhteydessä luunäytteet. Niistä analysoitiin rasva, tuhka ja tuhkan kivennäisainepitoisuudet (kalsium, magnesium, fosfori, natrium, kalium, sinkki, kupari, mangaani). Metacarpus sisälsi merkitsevästi vähemmän rasvaa ja enemmän tuhkaa kuin kylkiluu tai 4. polvinivelen luu. Eri luutyyppien Ca, P, Na ja Mn pitoisuudet olivat samaa suuruusluokkaa. Kylkiluut sisälsivät enemmän Mg, K, Cu ja Zn kuin muut luut.

Ruukin eläimillä kylkiluun Ca pitoisuus oli korkeampi mutta P pitoisuus alhaisempi kuin Jokioisten eläimillä. Ruukin eläinten luissa oli merkitsevästi vähemmän Mg mutta enemmän K ja Cu verrattuna Jokioisten eläimiin. Tutkimuksen tulokset antavat aiheen olettaa, että ruokinnalla voidaan vaikuttaa luutuhkan kivennäiskoostumukseen.

CONTENTS



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