Annales Agriculturae Fenniae

Maatalouden
tutkimuskeskuksen
aikakauskirja

Journal of the
Agricultural
Research
Centre

Vol. 27,3

Annales Agriculturae Fenniae

JULKAISIJA — PUBLISHER

Maatalouden tutkimuskeskus
Agricultural Research Centre

Ilmestyy 4 numeroa vuodessa
Issued as 4 numbers a year
ISSN 0570-1538

ALASARJAT — SECTIONS

Agrogeologia et -chimica — Maa ja lannoitus ISSN 0358-139X
Agricultura — Peltoviljely ISSN 0358-1403
Horticultura — Puutarhaviljely ISSN 0358-1411
Phytopathologia — Kasvitaudit ISSN 0358-142X
Animalia nocentia — Tuhoeläimet ISSN 0517-8436
Animalia domestica — Kotieläimet ISSN 0358-1438

JAKELU JA VAIHTO

Maatalouden tutkimuskeskus, Kirjasto, 31600 Jokioinen

DISTRIBUTION AND EXCHANGE

Agricultural Research Centre, Library, SF-31600 Jokioinen

This journal is selectively referred by Animal Breeding Abstracts, Automatic Subject Citation Alert, Bibliography and Index of Geology, Biocontrol News and Information, Biological Abstracts of Bioscience Information Service, Bulletin Signaletique: Bibliographie des Sciences de la Terre, Chemical Abstracts, Current Contents, Entomological Abstracts, Field Crop Abstracts, Horticultural Abstracts, Informascience, Referativnyj Zhurnal, Review of Applied Entomology (Series A), Review of Plant Pathology, Weed Abstracts.

PREFACE

The Jubilee Issue marks the occasion of the 90th anniversary of the Agricultural Research Centre of Finland, on August 11th 1988. Since its establishment in 1962, Annales Agriculturae Fenniae has served as the forum for the presentation research results of all fields studied at the Agricultural Research Centre. It thus seems most appropriate to present a multidisciplinary review of the current research and future plans in the format of a regular issue. A part of the articles in this issue report on new research results in the form of conventional scientific papers. Other articles provide a very thorough presentation of the historical background and development of a specific area of research. In some areas, this work has been well recognized internationally. Some writings are concerned with the introduction of future tasks upon which the efforts will be concentrated in the years to come. It is hoped that this Jubilee Issue will provide its readers with a sound overview of the activities and status of the research conducted at the Agricultural Research Centre.

Editor Jouko Sippola

THE OUTLOOK FOR AGRICULTURE IN FINLAND

KALEVI HEMILÄ

HEMILÄ, K. 1988. **The outlook for agriculture in Finland.** Ann. Agric. Fenn. 27: 167—170. (Nat. Board of Agric., SF-00170 Helsinki, Finland.)

BACKGROUND

The prospects for the development of Finnish agriculture are derived from the historic experience of our agricultural sector during the post-war period. Until the 1960s, continued rural settlement, the large-scale clearing of new arable land and the establishment of new farms meant increases in both the number of farmers as well as that of active farms up to the beginning of the 1960s. As a result of this background, the structural development of agriculture in Finland has lagged behind that of Swedish and Danish agriculture, for example.

Despite a decrease in the farm population since the 1960s, the segment of our population engaged in agriculture and forestry is still considerably large. According to the 1985 census, employment in agriculture and forestry accounted for approximately 10.6 % of the employable labor force. The share of agriculture alone was 8.4 %. In 1985, the number of people employed in agriculture and forestry exceeded 250 000. The indirect effects on employment by agriculture and forestry well illustrate the role this basic source of livelihood still has in present-day Finland. The jobs of approximately 500 000 Finns are either directly or indirectly dependent upon domestic agriculture and forestry.

During the past 30 years, efficiency in agricultural production as well as technological advancement has meant continuous growth in total production despite a decrease in the numbers of active farms and farmers. With the increase in production, overproduction has become the most difficult problem confronting our agricultural output.

Already in the 1960s and 70s, attempts were made to restrict agricultural production by various voluntary measures mainly. However, the increase in production efficiency covered the effects of these restrictive measures so that a reduction in total production was not brought about.

In 1983, the aggravated world market situation of agricultural products led to the application of strict quotas which were aimed at the control of domestic animal production. Subsequently, practical agricultural policy has been unilaterally focused on the restriction of production. The objectives of agricultural income and structural policies have been left aside. Growth in domestic animal production has been brought to a halt and overproduction has begun a rapid decline.

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The future prospects of Finnish agriculture were assessed by the Committee on Agriculture 2000 whose work was completed in the summer of 1987. The Committee has drafted a comprehensive program of agricultural policy in which very clear objectives have been set for the first time in Finland. As the basic goal of agricultural policy, the Committee has set the reduction of overproduction. Agricultural production is intended to be guided in such a manner that in the long-term the production of target price products (milk, beef, pork, lamb, eggs, rye, wheat, barley and oats) will correspond to the domestic level of consumption. Due to seasonal variation, this production goal will mean a slight surplus of domestic animal products. Control over the output of agricultural products by means of export subsidies will be abandoned as a rule.

By the end of this millenium, the goals set by the Committee on Agriculture will mean, among other things, that milk production will decline by at least 20 %. Many hundreds of thousands of hectares of cultivated arable land will be taken out of production. As the scope of the changes is great, effective measures will be required. The real reduction in production, as well as the structural development of agriculture as such will compound the problems of agricultural policies.

When examining the future prospects of agriculture, no grounds can be found for avoidance of the new line of the production policies. A renewed oil crisis or the greenhouse effect are flimsy arguments against an alteration of the reduction line chosen on the basis of economic facts. Our production costs are exorbitant and overproduction must be minimized.

Nor can the crop failures and bad year of 1987 alter the basic lines of production policy. The Committee on Agriculture has proposed that more attention ought to be given to contingency safety. According to the Committee's proposals, in order to assure contingency safety, agricultural products and the stockpiling of agricultural inputs ought to be further developed. A sufficient reserve of arable land ought to be kept in productive condition and input self-sufficiency should be increased. Preparedness in the event of bad years is also indicated in the proposals.

However, with regard to the quantitative goals of production, the most difficult problem to be solved in our agriculture is how agricultural income and structural policy will adjust to decreasing outputs; how the number of farmers and active farms will be developed. For example, what will be the size of the average farm and number of cattle? How will technology be utilized, etc.? In this regard, too, economic factors would appear to unavoidably indicate the need for larger units and a smaller number of farmers. Under the present production structure, it will not be possible to fulfill the goal of a legitimate level of income for farmers.

The internal structure of agriculture itself will lead to a further decrease in the number of farmers and farms. The Committee has estimated a decrease of one-third in both the numbers of farmers and active farms by the year 2000.

According to the Committee, the development of agricultural structure ought to proceed by safeguarding natural structural development. Structural policy will direct support to farms engaged in viable production. Particularly the granting of state-subsidized financing will have to operate on the assumption that the recipient farm family has possibilities for making a living in the long-term as well.

Agricultural policy support will primarily strive to protect the livelihood and living standard of farmers. If the number of farmers declines as predicted, the present levels of agricultural support can ensure farmers of a considerably better level of income even if the state should abandon export subsidies also.

The proposals of the Committee on Agriculture provide a positive framework for the development of a viable agricultural sector. The means and objectives of agriculture have finally been formed into a logical whole. Safeguarding the self-sufficiency of foodstuffs by domestic agricultural production has been accepted as the basic objective of agricultural production. The preservation of import protection has been proposed. The Committee has suggested that state funds saved from export subsidies be appropriated to agriculture, to other occupations in rural areas, to the creation of jobs, the conservation of settlement, as well as improvement in the income of farmers and other rural inhabitants. The above proposals well describe the accompanying effects by which the development of agriculture will, in the broadest sense, lead to the development of the whole countryside.

CONNECTIONS OF AGRICULTURE TO ALL RURAL DEVELOPMENT

Rural entrepreneurship has been sought as the means of compensation for decreasing agricultural production. The area which would most naturally compensate for decrasing agricultural production would be forestry.

The advancement of agriculture and forestry is based on the utilization of our forest resources. The felling savings of recent years and the efficient thinning required in forestry could be sensibly utilized to create plenty of permanent jobs in the countryside. In addition, various other subsidiary and associated sources of livelyhood provide possibilities for the diversification of rural occupations.

Furthermore, it is most important that agricultural adjustment be facilitated, and that investment in alternative means of rural occupations already be made now, concurrently with the obligatory decrease in agricultural production. The restriction of production, development of compensatory occupations as well as other measures that would support adjustment must be carried out simultaneously.

From the standpoint of rural and regional policy, viable agriculture constitutes the central basic source for the development to come. In addition to agricultural production, the conservation of rural vitality moreover requires the efficient utilization of all other resources of rural production and occupational opportunities as well. In rural development work it is essential that the natural potentials of each region be utilized to the maximum.

SUMMARY

Very rapid structural development of our agriculture will continue during the next few years. Internal transformation of agriculture itself will mainly occur by means of natural development. Production methods will develop. Aged farmers will retire from production. The number of active farms will decrease. Farm size will expand. The number of farmers will decrease. Overproduction will be reduced to the minimum. In addition, in the year 2000 Finland will be self-sufficient in agricultural products and production will still

take place chiefly by means of normal family farming.

The development of agriculture as such does not present very serious problems. However, the greatest difficulties will be caused by those effects which agricultural development largely has upon the entire society. The decrease in domestic agricultural production and the toughening of international competition by the liberation of world trade will signify a substantial decrease in food industrial jobs. Settlement of these questions firmly links our agricultural development to all structural changes and to the national economic development of Finnish society.

Manuscript received March 1988

Kalevi Hemilä
National Board of Agriculture
Mariankatu 23
SF-00170 Helsinki, Finland

SELOSTUS

Maatalouden yleiset näkymät Suomessa

KALEVI HEMILÄ

Maatilahallitus

Maataloutemme tulevaisuuden näkymiä selviteltiin Maatalous 2000 -komiteassa, joka sai työnsä valmiiksi kesällä 1987. Komitea laati maatalouspoliittisen kokonaisohjelman, jossa määriteltiin maataloudellemme ensimmäisen kerran hyvin selvät kehittämistavoitteet. Maatalouden tuotantopolitiikan perustavoitteeksi komitea asetti ylituotannon supistamisen. Tuotantoa ohjaamalla maataloustuotteiden vientituesta pääsääntöisesti luovutaan.

Tarkasteltaessa maatalouden tulevaisuuden näkymiä ei löydy perusteita uuden tuotantopoliittisen linjan valitsemiseksi. Myöskään vuoden 1987 satovahingot ja katovuosi eivät voi muuttaa tuotantopolitiikan peruslinjoja. Huomiota tulee kuitenkin kiinnittää aikaisempaa enemmän huoltovarmuuteen, kuten maatalouskomiteakin esitti.

Tuotannon määrällisiä tavoitteita vaikeammin ratkaistava ongelma maatalouden sisällä on kuitenkin siinä, miten maatalouden tulo- ja rakennepolitiikka sopeutetaan supistuviin tuotantomääriin: miten kehittyy viljelijäväestön ja aktiivitilojen määrä. Mikä on keskimääräinen tila- ja karjakoko. Millaista teknologiaa käytetään jne. Tässäkin suhteessa taloudelliset syyt näyttävät johtavan väistämättä suurempiin yksiköihin, pienempään viljelijäväestön määrään jne. Nykyisellä tuotantorakenteella ei pystytä toteuttamaan viljelijäväestön oikeudenmukaisen tulotason tavoitetta.

Maataloutemme rakennekehitys tulee jatkumaan hyvin nopeana lähivuosina. Maatalouden oma sisäinen muuttuminen tapahtuu lähinnä luonnollisen kehityksen kautta. Tuotantomenetelmät kehittyvät. Ikääntyvät viljelijät luopuvat tuotannosta. Aktiiviviljelijöiden määrä vähenee. Tilakoko kasvaa. Maatilojen määrä vähenee. Ylituotanto supistetaan hyvin vähiin. Myös vuonna 2000 Suomi on tärkeimpien maataloustuotteiden osalta omavarainen ja tuotanto tapahtuu edelleen pääosin normaaleilla perheviljelmillä.

Maatalouden omaan kehitykseen ei sisälly kovin suuria ongelmia. Suuria vaikeuksia aiheutuu kuitenkin niistä seurannaisvaikutuksista, joita maatalouden kehityksellä on laajemmin koko yhteiskuntaan. Viljelijäväestön väheneminen varsinkin Keski-, Itä- ja Pohjois-Suomessa aiheuttaa suuria alue- ja maaseutupoliittisia ongelmia. Kotimaisen maataloustuotannon supistaminen ja kansainvälisen kilpailun koveneminen maailmankaupan vapautuessa merkitsevät huomattavaa työpaikkojen vähenemistä elintarviketeollisuudessa. Näiden kysymysten ratkaiseminen kytkee maataloutemme kehittämisen kiinteästi koko suomalaisen yhteiskunnan rakennemuutoksiin ja kansantalouden kehitykseen.

PRIORITY AREAS OF RESEARCH AT THE AGRICULTURAL RESEARCH CENTRE

ESKO POUTIAINEN

POUTIAINEN, E. 1988. **Priority areas of research at the Agricultural Research Centre.** Ann. Agric. Fenn. 27: 171—176. (Agric. Res. Centre, SF-31600 Jokioinen, Finland.)

Finnish agriculture as well as the structure of rural life are undergoing a period of dramatic changes. The number of farms and farmers are decreasing rapidly and many farming villages, especially in the eastern and northern parts of Finland, are experiencing a decline in their populations. The situation is exacerbated by an imbalance between the production and consumption of major agricultural products. There are very limited possibilities to increase the production of cereal grains, pork, vegetables, berries and certain special plants. Public interest in the quality and nutritional aspects of food products has increased, and the effect of agricultural production on the environment has received more attention. Almost all agricultural products are utilized as raw materials by the food processing industry and are seldom sold directly to consumers. Therefore, the importance of research and development for the solution of current problems is stressed.

AGRICULTURAL RESEARCH TOWARDS THE YEAR 2000

A special study was recently performed to identify the general goals for agricultural research by the Committee on Agricultural Research of the Ministry of Agriculture and Forestry. The study proposed five general objectives for a national agricultural research program (Fig. 1).

The central idea of this research program is a multidisciplinary approach to existing problems. The whole production chain, from producers to consumers, should be covered simultaneously. Therefore, comprehensive research projects are often needed in order to satisfactorily solve today's problems. The national research objectives as set by the Committee on Agricultural Research have served as guidelines in the allocation of available funds for research projects. Moreover, the program set by the Committee provides a format by which annual and mid-term research programs may be planned.

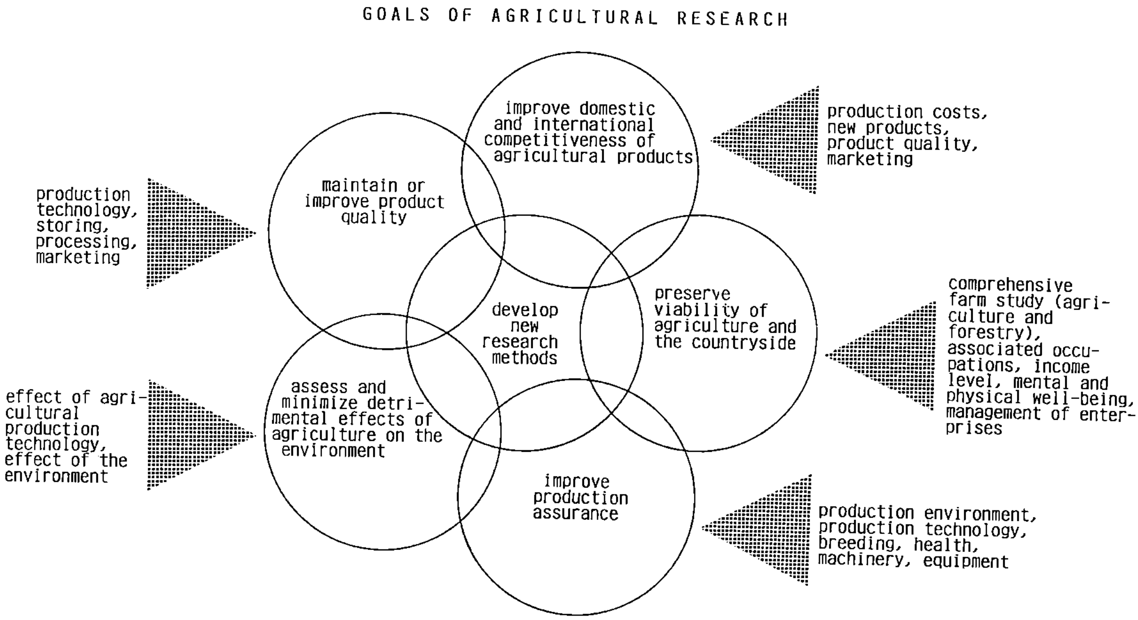

Fig. 1. Goals of the agricultural research.

IMPORTANT RESEARCH AREAS AT THE AGRICULTURAL RESEARCH CENTRE

The Agricultural Research Centre has identified four areas of major research based on the Agricultural Research Program 2000, as follows: 1) Research on the environmental effects of agriculture; 2) Quality aspects in agricultural production; 3) Research on decreasing the risks in production; 4) Research on improving the viability of rural life (alternative possibilities of production). In addition, special consideration will be given to the use of novel research methods and their application to agricultural research and production. Biotechnology is a most promising field in this regard, and it has become increasingly important. New application areas are open for innovative measurement and adjustment techniques based on microelectronics. New developments are also forseen in datatechnology and in the use of computers in biological research.

ENVIRONMENTAL RESEARCH

Approximately 10 % of the projects in the Agricultural Research Centres research program directly involve an environmental aspect, and a great many projects take environmental issues into consideration. This research seeks to minimize environmental risk due to agriculture. In addition, environmental constraints on agriculture have gained in importance.

Experiments on the utilization of manure have been in progress since 1982. The fertilization value of Finnish manure and the proper manuring techniques for grasses, cereals and potato have been thoroughly studied. The final objective is to be able to advise farmers on the optimal use of manure with a view to environmental protection.

The protection of ground water, waterways and soil is essential. In this connection, we have carried out extensive research on leaching losses of nitrogen in different soil types under grass and cereal crops. Research has been performed on both experimental fields and on lysimeters.

Various wastes are byproducts of the mining industry and sewage treatment plants. Wastes and sewage sludge have been studied in experiments to assess their effects on soil and plants.

The most important topic concerning environmental risk in agriculture is that of heavy metals deposition in the vicinity of industry and traffic. A research project entitled, "Effect of air pollutants on agricultural crops and soils" has been started in cooperation with the Finnish Meteorological Institute. Heavy metals will be analyzed in plant and soil samples collected from experimental fields.

Minimization of the use of herbicides and pesticides will further improve environmental quality.

RESEARCH ON THE QUALITY OF AGRICULTURAL PRODUCTS

Research on the quality of agricultural products includes the composition, nutritive value, taste, appearance and suitability for food processing. All plant and animal products must be both safe to use and promote good health. Special quality criteria have been presented for many raw materials used as components in the processing of high-quality special products.

In crop production, the quality of cereals grains (rye and wheat) is of special concern. Our environmental and climatic conditions border on the extreme for the cultivation of wheat, and quality is often low due to various factors. A comprehensive research project is in progress in which a breeding program for high quality is of special significance. Furthermore, cultivation technology, fertilizing, harvesting and processing are part of the project. Another plant which deserves special attention with regard to quality is the potato. A project which involves breeding, cultivation technology, harvesting as well as the storing of potatoes for home as well as industrial use is in progress.

The quality of vegetables and horticultural products is of particular importance, because most of these are directly consumed. The Agricultural Research Centre is studying the effects of cultivation techniques on the quality of vegetables cultivated outdoors or in glasshouses, as well as the quality of berries, fruits and flowers.

The quality of animal products is also of crucial significance today. In several research projects, objectives have been set for improvement in the composition of milk, meat and eggs according to consumer desires and to the recommendations of health specialists. Intensive research is in progress to meet this aim in the field of animal breeding and in the field of nutrition.

The quality aspects of Finnish agricultural products have also been studied in international research projects concerning the contents of mineral elements and harmful organic compounds.

The greatest risks in crop production and in the cultivation of horticultural plants are connected with soil base and weather conditions. Soil compaction due to heavy machinery is a very serious problem. Soil management research is therefore important, and the target is the development of cultivation techniques which would minimize tilling and reduce driving on fields. Soil physics has been emphasized in our research program.

Risk prevention in crop production puts plant breeding in a key position. Cereal breeding aims to produce new varieties high in yield and in quality which are hardy to climate and soil conditions. The primary cereals in the breeding program are spring and winter wheat, fodder and malt barley, oats and rye.

The breeding of oil plants (winter turnip rape, summer rape) aims to improve the composition of fatty acids (linoleic acid) and to lower the contents of erucic acid and glucosinolates. Research on the pea is concerned with the production of semi-leafless varieties. In addition, some faba bean breeding has been carried out. The problems in connection with potato breeding are those of quality and resistance.

Among grasses, timothy, meadow fescue, cocksfoot, perennial rye grass, bromegrass, red clover and alsike clover are being bred. Targets include adaptability to climatic and growth conditions, health, productivity and high quality yields.

Agricultural meteorology is an important area of research for risk minimization in plant production. The Agricultural Research Centre is actively involved in the development of a system for daily weather forecasting on a regional basis in cooperation with the Finnish Meteorological Institute and with the Agricultural Advisory Service. The service provided to farms includes the forecast (temperature, rainfall, etc.) for 2- or 5-day periods during the growing season, and recommendations for actual measures to be implemented at any time concerning the proper time for soil preparation and sowing, the control of pests and plant diseases, harvesting, etc. The Agricultural Research Centre supports the advisory service by providing observations and information. The weather forcast and the "Agricultural Outlook" are read onto a code-a-phone which a farmer can call.

Research in livestock production has aimed to minimize production risks. Animal breeding research involves fertility, immunity to diseases, productivity and assurance of the high quality of products. An essential part of these activities is the development of simple evaluation methods.

The target of feeding research is for more economical and balanced feeding. In this connection, the long indoor feeding period is of great importance. Much emphasis is therefore placed on home-produced protein sources. The most important topics in feeding research are grass silage, with reference to its preservation and feeding value. As a result of extensive investigation, the silage method has been found to be superior to other storage methods for grass, and is therefore widely practiced. Concentrated feed, straw, industrial wastes and byproducts, as well as biomass have been investigated as sources of grass silage.

The main activities of swine and poultry research concern different feeding methods and feed materials. Product quality as well as feeding factors that have an effect on quality are of current interest.

RESEARCH TO PROMOTE RURAL VIABILITY

Priority research areas for the promotion of rural viability include the possibilities for alternative production. Sheep farming is one type of alternative production which should have much growth potential. Therefore, sheep research is emphasized at the Agricultural Research Centre. In addition to productivity, the objectives of breeding (e.g. fenotype testing) and feeding research include the assurance of good quality meat, wool and skins.

An area which has already been intensively investigated is that of the production of fur-bearing animals. This research includes breeding, feeding, health and management, and should receive more emphasis in the future.

In the field of plant production, alternative production methods such as natural cultivation, have been of increasing interest and will be more intensively studied in the near future.

BIOTECHNOLOGY

Biotechnology is one of the major areas designated for future research at the Agricultural Research Centre. In plant breeding, tissue culture and haploid methods are being developed for breeding barley, turnip rape, potato, triticale and *Brassica.* The aim is to develop haploid techniques in order to produce abundant homozygote materials for further breeding or for comparison tests. Isolation, culture and regeneration methods have been developed with protoplasts, while fusion techniques have been developed for potato in order to find resistant cell lines.

Biotechnology has also been applied in plant protection research. In pest control research the target has been to minimize the use of pesticides. Particularly the study of natural enemies, such as antagonistic microbes, parasites, and predators is considered to be important. Natural pest control through habitat, management and by the augmentation of natural pesticides has been investigated. Many pests are already widely controlled by biological methods now in practice. The use of trap crops in the control of the rape blossom beetle seems to be of promise and will be further investigated.

The biological control of plant diseases has been under intensive study for many years and this work will continue. Some effective antagonists for soil and seed-borne diseases have been found from Finnish light-coloured sphagnum peat. Tests have been performed on diseases of crucifers, cucumber, cereals and carnation, and the results are most promising. Methods are being developed for the practical implementation of the new means of biological control.

To obtain virus-free, healthy plants, meristem culturing techniques have been applied. In the case of woody plant species, basic research is needed to determine the satisfactory growing conditions for each species and the cultivars of a breeding line.

In addition to the viruses of fruit trees, small fruit and ornamental plants, potato viruses as well as barley yellow dwarf viruses in cereals have been actively studied. For the reliable identification of viruses, tests based on the latest modern techniques, such as the ELISA, TR-FIA, electromicroscopy and nucleic acid analysis have been employed.

In animal breeding embryo transfer technique is a developing area that deserves considerable research effort. Emphasis has been on the application side but close contact is maintained with research teams working in gene technology and gene transfer in order to facilitate the transfer of some economically important characters.

Biotechnological principles have also been applied in the development of new methods in feed conservation and processing. Bacteria preparates and enzymes have been studied for use as preservatives in ensiling grass or other feed materials.

Manuscript received February 1988

Esko Poutiainen
Agricultural Research Centre
SF-31600 Jokioinen, Finland

SELOSTUS

Tutkimuksen painoalueet maatalouden tutkimuskeskuksessa

Esko Poutiainen

Maatalouden tutkimuskeskus

Maatalouden tutkimuskeskus suuntaa tutkimustaan entistä enemmän maataloustutkimuksen tavoiteohjelman "Maataloustutkimus 2000" mukaisesti yhteiskunnan tarpeista lähtevien ongelmien ratkaisemiseen. Tutkimusresursseja kohdistetaan erityisesti seuraavalle neljälle alueelle:

1. Maatalouden ja ympäristön vuorovaikutus
2. Laatutekijät maataloustuotannossa
3. Tuotantovarmuus eli riskien vähentäminen maataloustuotannossa
4. Maaseudun elinvoimaisuutta edistävä tutkimus

Tavoitteiden saavuttamiseksi nopeasti ja luotettavasti työhön sovelletaan entistä enemmän biotekniikan menetelmiä. Myös mikroelektroniikan ja tietotekniikan hyväksikäyttöä tutkimustyössä lisätään.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 177—190 (1988)

Seria AGROGEOLOGIA ET -CHIMICA N. 150 — Sarja MAA JA LANNOITUS n:o 150

MICROELEMENTS IN FINNISH SOILS: RESEARCH HISTORY AND CURRENT STATUS

MIKKO SILLANPÄÄ

SILLANPÄÄ, M. 1988. **Microelements in Finnish soils: Research history and current status.** Ann. Agric. Fenn. 27: 177—190. (Agric. Res. Centre, Dept. Soil Sci., SF-31600 Jokioinen, Finland.)

Investigations on microelements in Finland began in the 1930s in the form of field trials and studies on deficiency symptoms. Systematic, large scale studies based on chemical analyses began in the early 1950s; much earlier than in most other countries. Emphasis was first placed on the determination and survey of the total contents of microelements in soils, then on the development of methodologies and determination of plant available fractions. Radioactive and heavy metal pollution has been studied since the 1960s, and since the mid-1970s studies have been carried out also on an extensive international scale.

The evaluation of the status of various microelements in Finnish soils is based on both national studies and on international comparisons. In general, no serious problems due to microelements exist in Finland at the present time. Although there are relatively wide variations in the contents of many micronutrients in Finnish soils and crops, extreme contents are rare. Thus, the status of most essential micronutrients in Finnish soils is relatively good and in the international comparison Finland usually belongs to the medium group of countries where deficiency or toxicity problems are less likely than elsewhere. Micronutrient deficiencies which were common earlier, especially those of boron, copper and selenium, have been identified and are now, generally, under control due to fertilization based on systematic studies. In regard to the polluting elements, lead and cadmium, the status of Finland resembles that of developing countries. The contents of these elements are much lower in Finnish soils than in the soils of other European countries compared.

Index words: microelements, soil, plant, Finland.

I. HISTORY OF MICROELEMENT STUDIES IN FINLAND

A. Early field trials and traditional analytical studies

Among the first Finnish agricultural scientists to realize the importance of micronutrients for plant growth, and to carry out studies on micronutrients in soils and plants were Professor E. A. Jamalainen and Mr A. Tainio. The former extensively studied the behaviour of boron as the cause of "brown-heart" disease of rutabaga and "internal cork" of apples (e.g. JAMALAINEN 1935a, b, 1936a, b) while the latter concentrated first mainly on the role of copper, but later also that of other micronutrients in the nutrition of Finnish agricultural crops (e.g. TAINIO 1946, 1948). Of the other early micronutrient investigators, Dr. M. Salmi, is to be mentioned. His studies were focused mainly on the micronutrient status of Finnish peat soils (e.g. SALMI 1950). Although most of early micronutrient studies in Finland were based on the results of field trials, several studies employed chemical analyses with the traditional methodology.

B. Studies on total contents of microelements in soils

A new phase of Finnish micronutrient studies began in 1952, when the Institute of Soil Science of the Agricultural Research Centre received an excellent new piece of equipment, a 2-meter ARL grating spectrograph. This made it possible to begin more systematic studies on a number of microelements. At first, the investigations were concerned with the development of methodologies (e.g. LAPPI and MÄKITIE 1954) after which determinations of the total contents of microelements in Finnish soils were carried out on a large scale. These included micronutrients essential to plants and/or animals such as cobalt, copper, manganese, iron, molybdenum and zinc as well as other microelements, e.g. chromium, gallium, lead, nickel and vanadium, whose role in plant or animal nutrition was still not established. These studies were summarized by VUORINEN (1958).

C. Estimation of plant-available micronutrients

Although the total content of a micronutrient in soil may have an essential influence on its soluble or plant available content, availability may be dominated by other factors such as pH, organic matter, texture, clay minerals, moisture content, redox potential, etc. Thus total content is seldom a reliable index of the available micronutrient status of the soil.

When the lack of correlation between the total micronutrient contents of soils and the amounts taken up by plants was realized, most of the micronutrient studies began to concentrate on developing and testing new methods for estimating the contents of micronutrients in soils available to plants. In addition, the method would need to have enough extraction power to extract microelements chelated with organic matter as well as the exchangeable and readily soluble fractions, thus extracting microelement concentrations high enough to permit direct determination by atomic absorption spectrometry, a recently introduced technique. Another requirement set for the method was that it should be suitable for the simultaneous extraction of several microelements.

These studies, first conducted by Dr. O. Mäkitie, and later by Mr. E. Lakanen (e.g. MÄKITIE 1960, LAKANEN 1962, SILLANPÄÄ and LAKANEN 1969) resulted in a well recognized extraction method in which acid ammonium acetate-EDTA is used as an extractant (LAKANEN and ERVIÖ 1971a). This method was extensively examined and compared with other extractants both in Finland and abroad. In 1977, it was accepted as reference method by the European Research Network on Trace Elements (ANON. 1977) and in 1986 it was taken into routine use for soil testing in Finland (ANON. 1986a, b). At present, the AAAc-EDTA method is used mainly for extracting cationic microelements but studies on its suitability for extracting anionic micronutrients and macronutrients are in progress.

D. Studies on radioactive and heavy metal pollution

The increasing radioactivity of agricultural products due to fall-out from atmospheric nuclear testings in the early 1960s initiated a series of studies to get a better picture of the changes in the activity level within the food chain, i.e. soil-plant-animal/human, as well as to find ways to decrease the uptake by plants of radioactive elements from soils (e.g. LAKANEN and SALO 1964, LAKANEN and SILLANPÄÄ 1967, 1969). Interest in this line of study was renewed again after the Tchernobyl accident in 1986.

The general increase in interest in environmental aspects and heavy metal pollution in the 1960s, as well as the location of several institutes of the Agricultural Research Centre in the vicinity of a lead smeltery in Tikkurila can be considered as an impelling force behind number of studies which combined environmental and agricultural aspects. Of the earliest works on this subject, those of SALMI (1969), LAKANEN (1969), LAKANEN and ERVIÖ (1971b), RAJAMA (1973), ERVIÖ (1977) and HÅRDH (1977) are to be mentioned. In these, the polluting effects by traffic on fields close to highways as well as those of polluting factories were measured and evaluated. Since then, environmental aspects have been taken into account in almost all extensive agricultural investigations on microelements.

E. National and international microelement surveys

Until the 1970s the data on the nutrient status of Finnish soils concerned mainly macronutrients and were largely based on routine soil testing (e.g. KURKI 1963, 1972). Although these data already included some information on micronutrients and some studies with a limited number of sampling sites and elements (e.g. LAKANEN and SILLANPÄÄ 1967, LAKANEN 1969) had been carried out, our knowledge of the available supply of various micronutrients and polluting elements was still rather limited. More information was needed on the mineral contents of soils, basic food and fodder materials, effects of general fertilization practices, micronutrient applications, or polluting elements on the quality of crops to obtain a better understanding of the causes of and possibilities for correcting conceivable disorders. A more comprehensive general picture of soil nutrient status, their mutual relationships in different soil types and local variations was obtained in 1974—1978 when an extensive study on "Mineral Elements in Finnish Crops and Cultivated Soils" was carried out. This nationwide study, sponsored by the Academy of Finland and implemented in cooperation with Agricultural Research Centre and Kemira Oy, is apparently the largest and most comprehensive of its kind carried out to date. It consisted of analytical data on macro-, micro-, polluting and other elements (totalling 28 elements) based on plant and soil samples from over 2000 sites representing the entire agricultural area of the country, and more than 200 fertilizer trials. The results of this national study were published in 1978 in cooperation with several authors (ANON. 1978).

Despite hundreds of studies carried out in various countries in the field of micronutrients, the overall picture of the micronutrient status of soils has been very vague. This is because different methodologies have been employed by almost every laboratory in the analysis of soil and plant samples. Consequently, results have been scattered and fragmentary, and there has been very little basis for comparison. This has made interpretation of results very difficult; often impossible. In other words, scientists working in different laboratories have been "speaking different languages". This situation was realized in discussions between Finland and the FAO which led to the establishment of an international project called the "Trace Element Study".

The purpose of the study was to produce fresh information, on a worldwide basis, on the problems of a number of micronutrients under different soil, climatic and cultural conditions. The results would be comparable because all analytical work would be done by one laboratory thus the uniformity of the analytical methods to be used would be ensured. The study aimed to: 1) obtain a general picture of micronutrient status on a worldwide basis, 2) locate and limit the problem areas, soils and conditions where one or more of the micronutrients was likely to be deficient and which required more detailed future research and field experimentation; and, 3) provide guidelines for solving the problems in practice.

The thirty countries that participated in the study collected soil and respective plant samples (totalling about 7500 samples) from their agriculturally important areas and sent them to the Institute of Soil Science of Agricultural Research Centre in Finland for analysis. The complete results of the study are presented in the FAO Soils Bulletin No. 48 (SILLANPÄÄ 1982). In addition, more data on micronutrients has been collected in connection with current routine soil testing covering several micronutrients (e.g. KÄHÄRI et al. 1987).

Follow-up projects for both the national and the international extensive micronutrient surveys mentioned above are in progress at the present time.

During the last two decades soil and plant micronutrients have served as the subjects of four doctoral theses concerning four different micronutrients. In the first two (JAAKKOLA 1972, MÄNTYLAHTI 1982) the behaviour, availability to plants and factors affecting it, and the determination of molybdenum and manganese, respectively, were studied. SAARELA (1985) studied soil boron and especially the boron requirement of spring rapes, while YLÄRANTA's (1985) subject was selenium, its status, requirement and methods of correcting Se deficiency.

II. MICRONUTRIENT STATUS OF FINNISH SOILS AND CROPS

A. General

Our knowledge of the microelement status of the cultivated soils of Finland is based mainly on the studies mentioned in the previous chapter. The international data (SILLANPÄÄ 1982) provide an extensive global background against which Finnish data can be evaluated and interpreted. Although the study in which Finnish and international data are directly comparable consists only of the southern part of Finland, it still covers about three-fourths of the agricultural area of the country. The other national data (e.g. ANON. 1978, KÄHÄRI et al. 1987) supply more detailed information on local conditions including geographic distributions and the roles of various soil types, etc. consisting in all of Finland's cultivated fields.

For some micronutrients (e.g. B, Cu, Fe, Zn), and evaluation of the level of the Finnish data on an international scale can be made easily because the data have been obtained by the same analytical methods. In some cases (e.g. Mn, Mo), only part of the data are directly comparable and more interpretation is needed to find the right position in the "international micronutrient fields" for Finnish values obtained by divergent methodologies. In the following sections, data are presented on some important microelements for which both nationally and internationally comparable results are available.

B. Boron

In the international comparison the mean Finnish B content of the indicator crop, wheat, as well as the mean hot-water-soluble soil B value are slightly below the respective international values and thus in the "international boron field" Finland belongs to the medium group of countries (Fig. 1).

It should be understood, however, that the values plotted in the graph are mean values which as such only give a rough idea of the micronutrient status in the countries concerned. There is always some, sometimes substantial, internal variation in the soil and plant values within each country. For example, in Iraq which has by far the highest national mean B values, every sixth B content measured falls within the lower international quartile.

Although deficiency of B can be suspected at some locations in almost every country, low B soils seem to be relatively most common in the Far East (Nepal, Philippines, Thailand, India) and in some African countries (Nigeria, Malawi, Zambia). Problems due to excess B are most likely to arise in Iraq, Mexico, Turkey, Malta and Pakistan. Irrigation with B containing waters is often cited as a cause of high B content in soils and crops. In Iraq, for example, irrigated soils and crops (grown on them) have four times as high B contents as those of rainfed sites. It also seems that the high electric conductivity of a soil is often accompanied by a high boron content.

The great majority of the Finnish soil and plant samples analyzed in the above study show internationally normal B contents. There are no indications of B toxicity, but at some sites a possible latent though not acute deficiency can be suspected. This is in agreement with soil

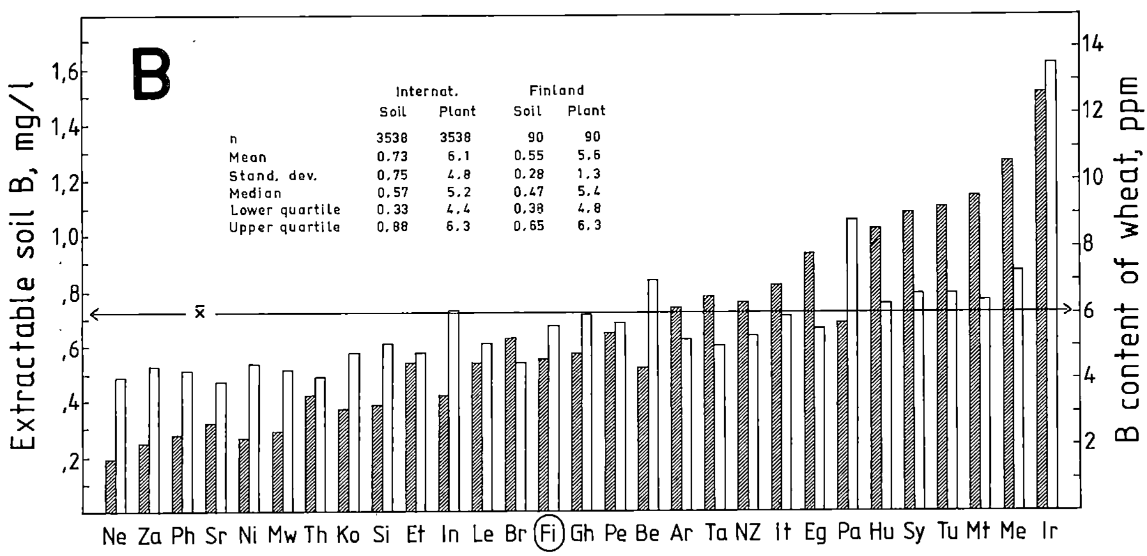

Fig. 1. National mean values of hot-water-extractable soil boron (left columns and left ordinate) and respective boron contents of the indicator plant, wheat (right columns and right ordinate). The scales have been adjusted so that the horizontal line ($\bar{x}$) indicates the international mean values for both the soil and the plant boron. Numerical values of other soil (mg/l) and plant (ppm) statistical parameters are given in the graph for both the whole international material and Finland. The country columns are in an approximate order of magnitude taking into account both the soil and plant boron contents. Countries: Ar = Argentina, Be = Belgium, Br = Brazil, Eg = Egypt, Et = Ethiopia, Fi = Finland, Gh = Ghana, Hu = Hungary, In = India, Ir = Iraq, It = Italy, Ko = Korea Rep., Le = Lebanon, Mt = Malta, Mw = Malawi, Me = Mexico, Ne = Nepal, NZ = New Zealand, Ni = Nigeria, Pa = Pakistan, Pe = Peru, Ph = Philippines, Si = Sierra Leone, Sr = Sri Lanka, Sy = Syria, Ta = Tanzania, Th = Thailand, Tu = Turkey, Za = Zambia.

testing statistics 1981—85 (KÄHÄRI et al. 1987) where less than one per cent of the soils fall into the two highest B classes and less than five per cent into the two lowest B classes. According to the same source, clay soils have the highest mean soluble B contents while some sand and silt soils are the lowest in B. Geographically, the soils of the southwestern parts of Finland, especially those of the Ahvenanmaa archipelago, are on average richer while the soils of North Karelia, Kuopio and the Central Finland Provinces are somewhat poorer in B than in other parts of the country.

Although the B status of Finnish soils seems to be satisfactory at present, it has not always been so. B deficiency was relatively common a few decades ago, but mainly due to the systematic addition of B (0.05 %) to most compound fertilizers it has become quite rare. This development can be seen as a systematic rise of the average soil testing B values since the 1960s. For the five-year periods 1966—70, 1971—75 and 1976—80 the respective average B contents of the Finnish soils were 0.41, 0.45 and 0.48 mg/l and thereafter the annual averages for the years 1981—85 were 0.57, 0.60, 0.60, 0.70 and 0.70 mg/l, respectively (KURKI 1982, KÄHÄRI 1985, KÄHÄRI et al. 1987). Because of this development the B content of the fertilizers was decreased to the level of 0.03 per cent in 1986 (ANON. 1986c).

C. Copper

The Finnish national averages for Cu contents in the indicator plant and soils are slightly on the low side in the international comparison (Fig. 2). The more detailed data of the study, not presented here, indicate that deficiency of this micronutrient is relatively common in most of the African countries studied, but also that many soils of Finland and New Zealand are low in available Cu. Cu deficiency seems to be rare elsewhere. Exceptionally high Cu values were frequently found in samples from the

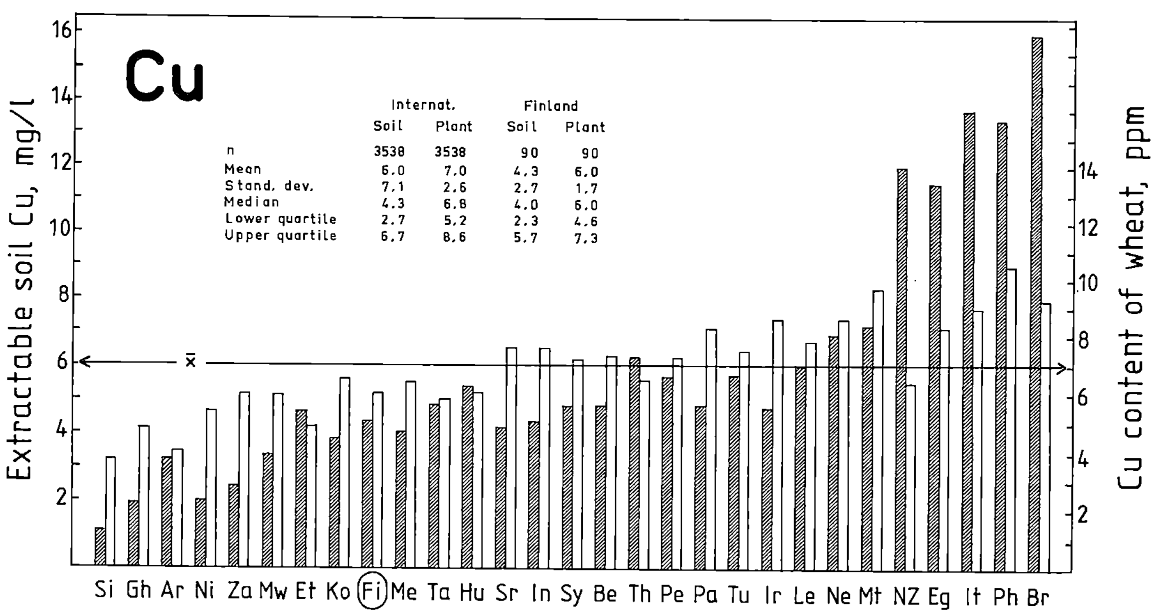

Fig. 2. National mean values of acid ammonium acetate-EDTA extractable soil copper (left columns) and respective copper contents of the indicator plant (right columns). For country abbreviations and other data given in the graph see the text for Fig. 1.

Philippines, Brazil, Italy and Tonga[1] but only occasionally elsewhere.

The variation in the Cu contents of Finnish crops and soils is relatively wide. About ten per cent of the measured values fall in the upper international quartiles and about thirty per cent in the respective lower quartiles. Still, no extremes exist in the Finnish material. The average AAAc—EDTA extractable Cu content of Finnish soils (4.3 ± 2.7 mg/l) is lower than that (4.7 mg/l, n = 431) reported earlier by SILLANPÄÄ et al. (1975) but higher than the mean (2.8 ± 2.9 mg/l) of a substantially larger sample material (n = 2015) collected from timothy fields (SIPPOLA and TARES 1978). The lower mean of the latter study is partly due to the substantial number of samples from the northern part of the country where coarse mineral soils dominate. Like peat soils, these are usually poor in Cu while the Cu status of clay soils, especially heavy clays found only in the southern parts of the country, is fairly good. These differences among the soil types are reflected fairly well in the Cu contents of timothy (KÄHÄRI and NISSINEN 1978). According to all of the above studies texture seems to be one of the dominating soil factors that determines the Cu status of soils. In addition, some earlier investigations (e.g. TAINIO 1960, TÄHTINEN 1971) indicate that copper deficiency occurs quite frequently in Finland, especially in the peat soils and in the coarse textured mineral soils of the northern part of the country.

According to soil testing statistics (KURKI 1982, KÄHÄRI et al. 1987) a slight decline in the Cu contents of Finnish soils had taken place until about 1970, but since then some improvement has been observed. This can be attributed to the use of fertilizers containing copper which has steadily increased from the level of 61—87 g Cu/ha in 1966—70 up to about 300 g/ha in 1983—87 (KEMIRA 1973, 1987). The most substantial increases have been recorded for the northern provinces.

D. Iron

In the global sample material (Fig. 3) the Finnish national mean of extractable soil iron (569 ± 367 mg/l) is higher than the mean of any other country. The average AAAc-EDTA extractable Fe content of 2015 Finnish soils (677 ± 656 mg/l) presented by SIPPOLA and TARES (1978) was even slightly higher. Still, the respective mean Fe content of the indicator plant (64 ppm, Fig. 3) is first the eighth highest and exceeds the international average by 3 ppm only. On the other side the variation of plant Fe compared to soil Fe is narrow. Thus, for example the mean plant Fe contents of 16 countries fall between 60 and 66 ppm and even the highest mean (Philippines) is less than 80 ppm. The lowest mean plant and soil Fe values recorded are those of Malta and Mexico.

Although the AAAc-EDTA extractant used is relatively good for Fe, there is still more discrepancy between the results of soil and plant analyses than in case of other micronutrients of the above study.

In Finland, the role of different soil types as a source of available Fe cannot be clearly established. Some organic soils and fine mineral soils, however, seem to be able to supply more Fe to plants than most coarse mineral soils (SIPPOLA and TARES 1978, KÄHÄRI and NISSINEN 1978). Geographically no distinctly high nor low Fe areas in Finland can be distinguished and neither deficiency nor toxicity of Fe has been confirmed.

1) Tonga samples were included in the New Zealand material.

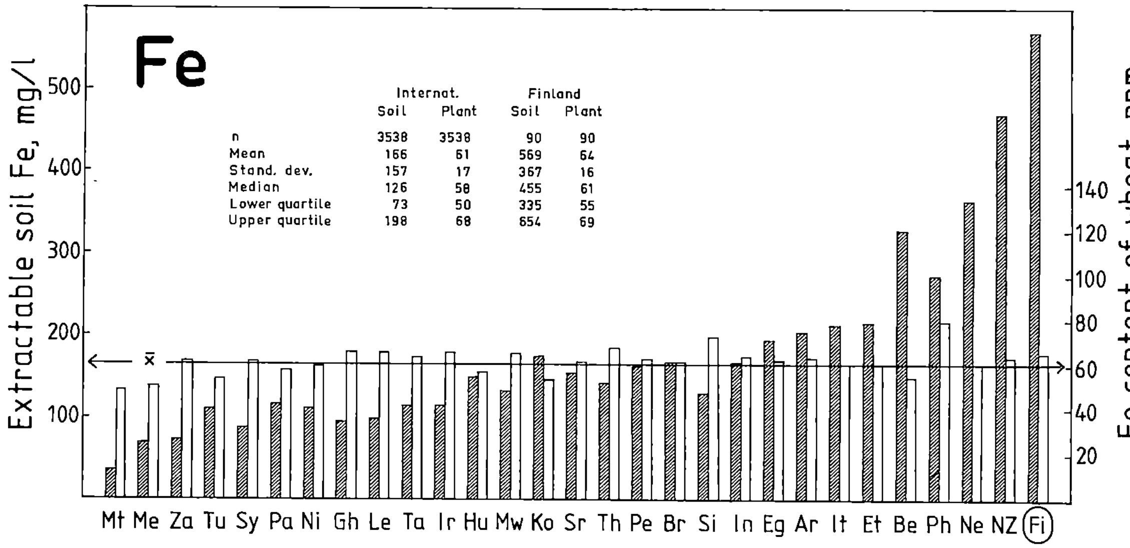

Fig. 3. National mean values of acid ammonium acetate-EDTA extractable soil iron (left columns) and respective iron contents of the indicator plant (right columns). For country abbreviations and other data given in the graph see the text for Fig. 1.

E. Manganese

A low availability of manganese is usually associated with alkaline soils and an excess of Mn with acid soils. This is reflected even in the national mean Mn values shown in Fig. 4[1]. The five countries on the left with the lowest Mn status (Malta, Syria, India, Pakistan, Iraq) have strongly alkaline soils with average pH ($CaCl_2$) over 7.5. Also in the next four countries the average pH exceeds 7.0. Respectively, in the eleven high-Mn countries on the right the national mean pH is lower than 6.0 and in the three rightmost (Zambia, Brazil, Malawi) below 5.4. Finland belongs to the medium group of countries having national mean and median soil and plant values which are relatively close to the respective values for the whole international material. The variation ranges of the Finnish soil and plant Mn contents are relatively narrow and thus, the material does not include extreme values. The highest Mn contents were found in samples collected from sites where acid soil (pH < 5) prevailed and the lowest from sites with soils of only moderate acidity.

The results of the above international study (SILLANPÄÄ 1982) are not directly comparable to those of SIPPOLA and TARES (1978) due to the lack of pH-correction in the latter soil data, nor to those of KÄHÄRI and NISSINEN (1978) because of a different indicator crop. According to the latter study, Mn seems to be most available to plants in organic soils: Carex peat, mull, Sphagnum peat, and gyttja. These soil types are generally acid with average pH (H_2O) ranging from 4.6 to 5.3.

Mn is somewhat more strongly fixed in moderately acid mineral soil types the mean pH of which varies from 5.6 to 5.8. Geographically, a systematic rise was found in the Mn content of timothy toward the north. The average Mn

1) The soil Mn values presented in the graph have been obtained by the AAAc—EDTA method with pH-correction and have not been published earlier. Thus, these differ from those (pH-corr. DTPA-values from the same sample material) presented in the FAO Soils Bull. 48. The former solution extracts average about nine times as much Mn as the latter. The correlation (r) between the two methods was 0.840***.

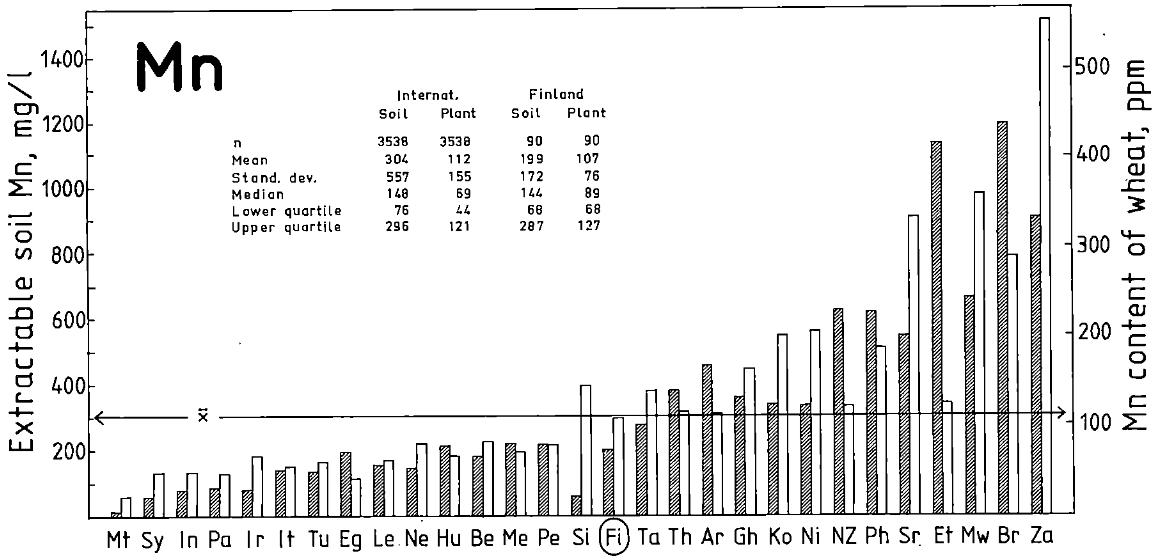

Fig. 4. National mean values of acid ammonium acetate-EDTA extractable soil manganese corrected for pH (left columns) and respective manganese contents of the indicator plant (right columns). For country abbreviations and other data given in the graph see the text for Fig. 1.

contents of the crop in the five cultivation zones from south to north were: 58, 60, 62, 75 and 88 ppm. This is in agreement with the respective decline in the average soil pH: 5.70, 5.64, 5.60, 5.48 and 5.34.

Both the deficiency and the toxicity of Mn are rare in Finnish conditions. However, in heavily limed sugarbeet fields the deficiency of Mn, actual or latent, has become relatively common in the southern part of the country. In curing the deficiency of Mn both foliar and soil applications have been practiced. In the latter case the best results have been obtained by the fertilizer placement method (ERJALA 1986).

F. Molybdenum

Unlike manganese, molybdenum deficiency seems to be most widespread in countries with acid soils such as most African countries, especially Sierra Leone, Zambia, Ghana, Malawi and Nigeria (Fig. 5). Low Mo values were frequently recorded also in samples from Brazil, New Zealand and Nepal. The countries with the lowest Mo status are on the left in the graph. The soils of the four first from the left have an average pH ($CaCl_2$) below 5.5 and even the next eight below 6.1. High Mo contents in soils and plants were most typical for Pakistan and Iraq. The national mean pH of the soils of the six countries from the right of the graph is 7.1 or higher, and that of the three on the extreme right exceeds 7.7. In addition to soil pH the practice of continuous irrigation seems to play an important role in supplying soils and plants with Mo. For example, in Iraq the Mo content of irrigated soils was fourfold and that of plants sixfold compared to respective values from the rainfed fields.

The location of Finland in the "international Mo field" (Fig. 5) is in the center. The Finnish national mean soil and plant Mo values fall somewhat below the respective international mean values, but both medians are approximately at the same level as the international medians for soil and plant Mo. In spite of the

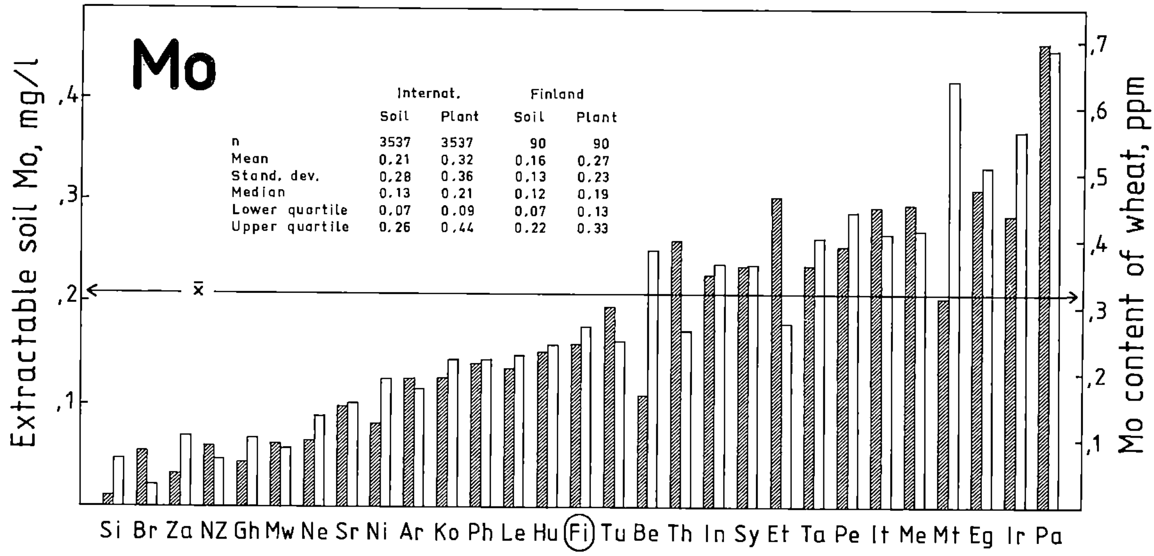

Fig. 5. National mean values of ammonium oxalate-oxalic acid extractable soil molybdenum (left columns) and respective molybdenum contents of the indicator plant (right columns). For country abbreviations and other data given in the graph see the text for Fig. 1.

relatively wide variation of Finnish soil and plant Mo contents the sample material does not include any extreme values. The highest Mo values were found in samples from sites where the soils have pH above the average and are medium textured, while the lowest values were recorded from sites of low soil pH and either coarse or fine soil texture. In coarse textured soils low Mo values are apparently due to low total contents and in fine textured soils due to low plant availability. Geographically, the distinction between high and low Mo areas is not clear. However, the Ahvenanmaa archipelago deviates from the Finnish mainland with its higher Mo status apparently due to a higher pH of soils (SIPPOLA and TARES 1978, PAASIKALLIO 1978). The mainland Mo status of the soils of some southern and northern provinces seems to be lower than that elsewhere in the country. The above materials do not indicate any serious Mo problems in Finland. However, heavy nitrogen applications (300—450 kg N/ha/year) commonly practiced by fodder producers may induce Mo deficiency on acid soils if the pH is not kept at a reasonable level by liming (RINNE et al. 1974).

G. Zinc

Because of wide variations in soil and plant zinc contents a deficiency of Zn can be suspected to occur somewhere in almost every country, Belgium and Malta being the most likely exceptions (Fig. 6). It seems to be most widespread in Iraq, Turkey, India and Pakistan, but especially in several other countries such as Syria, Lebanon, Nepal, Italy and Mexico, shortages of Zn may exist locally. High Zn status seems to be most typical for the soils of Belgium, Malta, Korea and Ethiopia. Industrial pollution is likely to be at least partly responsible for the high Zn values measured from the soils and crops of such an industrialized and densely populated country as Belgium, where industrial pollution may vary from 1 to 20 kg Zn/ha/year by region (WIJNDAELE and COTTENIE 1981). The respective

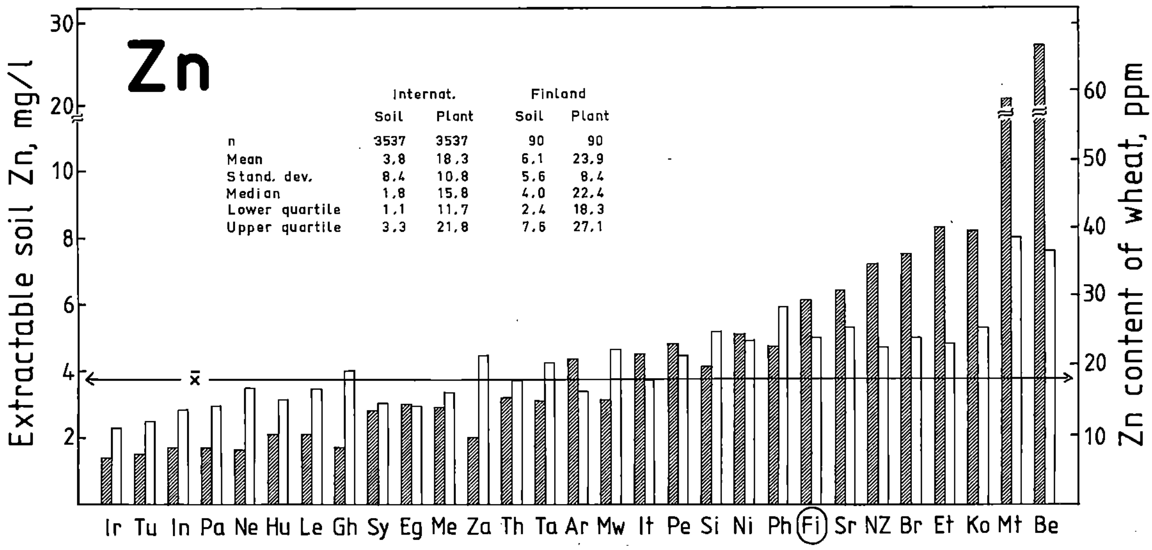

Fig. 6. National mean values of acid ammonium acetate-EDTA extractable soil zinc corrected for pH (left columns) and respective zinc contents of the indicator plant (right columns). For country abbreviations and other data given in the graph see the text for Fig. 1.

atmospheric fall-out in southern Finland, for example, is about 0.1 kg Zn/ha/year (ANON. 1986—1988).

The national averages for both plant Zn and extractable soil Zn are distinctly above the respective international averages (Fig. 6). About one half of the individual soil and plant Zn contents measured from Finnish sample materials fall within the upper international quartile. Because of a relatively narrow variation, however, very high Zn values are rare. Geographically, the distribution of extractable Zn contents of Finnish soils is not clearly defined. According to SIPPOLA and TARES (1978) the extractable Zn contents seem to increase generally toward the northern parts of the country while the opposite has been reported by KÄHÄRI et al. (1987). The reason for these contrasting results apparently lies in different analytical methods, the former (AAAc-EDTA) favouring the easily soluble fractions while the latter, acid-soluble Zn, reflects more the total Zn reserves. Similarly, the former method extracts more from coarse mineral soils and the latter indicates more ample Zn reserves of clays. Since 1986 the AAAc-EDTA extraction methods has been in routine use also in soil testing.

Although deficiency of Zn in agricultural crops has not been reported in Finland it seems possible that locally the Zn content of fodder crops is too low for animals. For example, the Zn content of our most important hay crop, timothy, is usually around 30 ppm (e.g. LAKANEN 1969, KÄHÄRI and NISSINEN 1978, YLÄRANTA and SILLANPÄÄ 1984) while the Zn requirement of lactating dairy cows is 40 ppm (NRC 1978). This has led to Zn supplementation of some of the compound fertilizers produced in Finland. Studies on the Zn nutrition of cattle are in progress.

H. Other microelements

Cobalt, lead, cadmium and selenium were originally not included in the comparative international study on microelements (SILLAN-

PÄÄ 1982) but analyses of the first three mentioned elements in soils were carried out later on.

According to preliminary results the average AAAc-EDTA extractable **cobalt** content of Finnish soils, 0.8 mg/l, is among the lowest of the thirty countries studied and only about one-fourth of the international mean (3.4 mg/l). The low level of extractable Co content in Finnish soils was confirmed by SIPPOLA and TARES (1978) who reported an average of 0.52 mg/l for the whole country. The highest national mean Co contents, from 6 to 10 mg/l, were found in the samples of Brazil, Lebanon, Thailand and Tanzania. The role of Co in Finnish agriculture needs to be studied further in detail.

The mean AAAc-EDTA extractable **lead** content of Finnish soils, 2.5 mg/l, corresponds the level measured from most developing countries, being distinctly lower than the national mean values of the other European countries compared: Malta 34, Belgium 13, Italy 12 and Hungary 6 mg/l. Equally low Pb contents in Finnish soils, aver. 2.0 mg/l, were reported also by SIPPOLA and TARES (1978) who registered a clear decreasing tendency in the extractable Pb in the five cultivation zones from south to north: 3.4 > 2.6 >1.9 > 1.8 >1.5 mg/l.

The national mean of AAAc-EDTA extractable **cadmium** content in Finnish soils, 0.11 mg/l, falls within the same range as those of the developing countries, ranging from 0.02 to 0.20 mg/l. This is clearly lower than the corresponding soil Cd contents of the five other developed countries in the study: Hungary 0.17, Italy 0.18, New Zealand 0.23, Malta 0.26 and Belgium 0.37 mg/l. The average Cd content of 209 Finnish soils 0.06 mg/l (min 0.01 max 0.20 mg/l) reported by SIPPOLA (1985) is still somewhat lower than the Finnish mean presented above.

Data on **selenium** from the comparative international study are not yet available. The awareness of the generally low Se status of Finnish soils and crops is based mainly on comparisons of the Se contents of various Finnish cereals, grasses and other crops and products to respective foreign data (e.g. OKSANEN and SANDHOLM 1970, SIPPOLA 1979, YLÄRANTA 1985). Initially, the shortage of Se in fodder was corrected by adding Se to industrially produced feeds, concentrates and mixtures, but since 1984, mainly on the basis of studies by YLÄRANTA (1985), Se has been added to most Finnish compound fertilizers in order to raise the Se content of plants to the desired level. Follow-up studies to control the Se level are in progress.

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Manuscript received March 1988

Mikko Sillanpää
Agricultural Research Centre
Department of Soil Science
SF-31600 Jokioinen, Finland

SELOSTUS

Hivenaineet Suomen viljelymaissa: tutkimushistoria ja nykytilanne

MIKKO SILLANPÄÄ

Maatalouden tutkimuskeskus

Hivenainetutkimukset alkoivat Suomessa 1930-luvulla perustuen kenttäkokeisiin ja kasveissa esiintyviin puutosoireisiin. Laaja, kemialliseen analyysiin perustuva systemaattinen tutkimus alkoi 1950-luvun alussa eli paljon aikaisemmin kuin useimmissa muissa maissa. Painopiste oli ensin maan hivenaineiden totaalipitoisuuksien määrittämisessä ja kartoituksessa ja siirtyi sitten uusien menetelmien kehittämiseen ja kasveille käyttökelpoisten fraktioiden määrittämiseen. Radioaktiiviset hivenaineet ja raskasmetallit ovat olleet tutkimuskohteina 1960-luvulta alkaen ja laaja kansainvälisyys on antanut leimansa tutkimuksille 1970-luvun puolivälistä lukien.

Suomen viljelymaiden hivenainetilanteen arviointi perustuu sekä kansallisella tasolla suoritettuihin että kansainvälisiin, vertaileviin tutkimuksiin. Mitään laajoja tai vakavia hivenaineongelmia ei Suomessa tällä hetkellä ole. Vaikka Suomen viljelymaiden hivenravinteiden pitoisuuksissa onkin melko laajaa vaihtelua, äärimmäisarvot ovat harvinaisia. Niinpä Suomen peltojen ravinnetila useimpien välttämättömien hivenravinteiden suhteen on melko hyvä. Kansainvälisessä pitoisuusvertailussa Suomi sijoittuu useimmiten siihen maiden keskiryhmään, jossa hivenravinnepuutos- tai -myrkytysongelmat ovat vähemmän todennäköisiä kuin muissa maissa. Ennen melko yleiset hivenravinteiden, erityisesti boorin, kuparin ja seleenin, puutokset on tunnistettu ja saatu pääosin hallintaan systemaattiseen tutkimukseen perustuvalla lannoituksella. Raskasmetallien, lyijyn ja kadmiumin, suhteen Suomi muistuttaa kehitysmaita. Niiden pitoisuudet ovat Suomen viljelymaissa paljon alhaisempia kuin muissa vertailussa mukana olleissa Euroopan maissa.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 191—197 (1988)

Seria ANIMALIA NOCENTIA N. 123 — Sarja TUHOELÄIMET n:o 123

THE CURRENT STATUS OF PLANT PROTECTION AND OUTLOOK FOR THE NEAR FUTURE

MARTTI MARKKULA

MARKKULA, M. 1988. **The current status of plant protection and outlook for the near future.** Ann. Agric. Fenn. 27: 191—197. (Agric. Res. Centre, Dept. Pest. Inv., SF-31600 Jokioinen, Finland.)

Chemical control has reached its culmination in Finland. An increased use of pesticides will not improve economic results. Current research is concerned with the possibilities to improve and reduce the use of pesticides.

Biological control of pests has been common in Finnish greenhouse cultivations since the beginning of the 1970s. The control of *Thrips tabaci* by means of the predatory mite *Amblyseius barkeri* has started in greenhouses and research has begun into the biological control of the recently arrived thrips *Frankliniella occidentalis.*

Biological control methods are being developed for outdoor cultivations for the control of pests and plant diseases. The control of several soil- and seed-transmitted fungal diseases by a preparation of actinomycetes is developed.

New results for practical plant protection are expected from developments in biotechnology and resistance breeding.

Weeds will also continue to be controlled almost exclusively by herbicides. The quantities of herbicide used will decrease as they become more effective. Environmental safety will be emphasized more than before in the registration of pesticides.

Index words: herbicides, insecticides, fungicides, biological control, biotechnology, plant resistance.

Nowadays, methods of chemical control are the main tools for the prevention of damages caused by plant diseases, pests and weeds. This is specifically due to the excellent effectiveness of pesticides, ease of use and economy. Annual pesticide sales in Finland total FIM 150 million (HYNNINEN and BLOMQVIST 1987). This sum has been calculated from producers' prices before value added tax. At current prices and present quantities sold, users pay some FIM 200 million annually for pesticides. Converted to active ingredients the annual quantity used is approximately 2000 tons. The application of pesticides peaked in 1980. In that year, 2 600 tons active ingredients of pesticides were sprayed in cultivated fields (TIITTANEN and BLOMQVIST 1981).

Up to the late 1950s, insecticides were the most commoncly and widely used pesticides. With the advent of selective compounds for the control of weeds, it became possible to destroy weeds in most crops. The use of herbicides thus rapidly became commonplace. Initially, it surpassed the use of insecticides, and shortly thereafter also the use of all other pesticides. Herbicides currently account for the majority, 75 %, of pesticide active ingredients used. The share of insecticides, acaricides and rodenticides is about 15 % and that of fungicides 5 %. Of the total amount only 5 % is used for forest protection.

The use of pesticides against plant diseases and noxious animals has not increased during the past ten years. Current choices of compounds and quantities used enable the control and management of nearly all plant diseases and noxious animals. Usage has therefore stabilized, and it may be said that usage has adjusted according to real need. During those years when plant diseases and pests are exceptionally abundant more control chemicals are spread onto fields and gardens that usual. After such exceptional periods the use of chemicals returns to former levels.

In practice, the resistance of pests to pesticides has not been of great importance. If some resistance has appeared to certain pesticides, other products have been used to get better results. Of the animal pests living on plants, only the peach aphid *Myzus persicae* (Sulz.) and the two-spotted spider mite *Tetranychus urticae* (Koch.) have been observed to have resistance of economical importance (MARKKULA and KURPPA 1985).

During the Second World War Finland's fields became weed-ridden due to lack of care. The situation became aggravated in the 1950s when threshing harvesters became widespread. The amount of weeds in dry weight exceeded 1000 kg per hectare (MUKULA 1974). After over thirty years of chemical and mechanical control weeds in our fields have been reduced by more than two-thirds (ERVIÖ and SALONEN 1987).

Nowadays, the cultivated fields in Finland cover ca. 2.2 million hectares. About half of the fields is treated yearly by pesticides and the other half is farmed without any pesticides. One can estimate that of the total cultivated area, 25 % is treated once, 20 % twice, 4 % three or four times and 1 % five times a year (MARKKULA 1985).

Among highly developed nations Finland uses least pesticides. Due to our northern location and small-sized scattered fields widespread epidemic diseases and mass appearances of pests are rare. Moreover, nowadays our growers know about the results of research and utilize extension services and their own experience in applying pesticides only when necessary. Preventive calendar sprays at pre-determined developmental stages of plants are no longer in use.

Registration procedures for pesticides more stringent

The aspect of safety to users, consumers and to the environment has become more important in the current preliminary assessment of pesticides. Carcinogenic, mutagenic and teratogenic characteristics of compounds are considered during the registration process and followed after approval. Whenever it is established that a compound may have harmful effects during normal agricultural use, as sales permit is not granted and the sale of earlier, approved products is prohibited.

Such pesticides which accumulate and become concentrated in the natural foodchain or that are known to produce other permanent, destructive effects on the natural environment have not been used for years in Finland. The sale and use of DDT as well as other chlorinated hydrocarbons was severely restricted in 1971, and the compounds were completely banned at the beginning of 1977 (MARKKULA 1973), MARKKULA and HILTUNEN 1982).

The new system of pesticide registration in 1983 put hazards and environmental protection on a par with biological effectiveness and usability. The Pesticide Commission, which is the central decision-maker has representatives from all government agencies concerned with the safe use of pesticides.

Few effective natural means

Biological pest control has been popular for some 20 years and is widely used here in greenhouse cultivations. Growers of cucumber and tomato utilize control organisms instead of pesticides to ensure their harvest. In practical control, the use of *Phytoseiulus persimilis* A.-H., *Encarsia formosa* Gahan and *Aphidoletes aphidimyza* Rond. have become well established (MARKKULA and TIITTANEN 1982). The biological control of thrips by means of the predatory mite *Amblyseius barkeri* (Hughes) predatory mites will begin soon (LINDQVIST and TIITTANEN 1989).

For outdoor cultivation there are few applicable and sufficiently effective biological or other natural methods. Covering the plant stand with net after sowing and planting is effective and has recently become a commonly used method. The selection of growth site, crop rotation, sufficient and balanced fertilization, proper sowing time and repeated harrowings provide a good foundation for the control of plant pests and diseases, but cultural methods are nearly always not sufficient. When pest damages threaten chemical control must be used for economic results.

During the past few years the Department of Pest Investigation at the Agricultural Research Centre has developed natural control methods, as an example the control of the rape blossom beetle *Meligethes aeneus* (F.) in extensive cauliflower cultivations where these beetles have occurred as new pests (HOKKANEN et al. 1986). By sowing the borders and interior of extensive cauliflower cultivations with the trap plants sunflower, marigold and turnip rape, damages to cauliflower by the blossom beetle have been prevented nearly completely. Early sown turnip rape appears to be the most effective of the trap plants.

Many natural methods such as ash sprinkled onto plants as well as sprayings with gelatin and pine soap are suitable for home gardens, since the results need not be optimal. However, for those who cultivate plants for their livelihood, these methods are not sufficient.

Research on the use of pheromones has been focused on monitoring of lepidopterous pests. Nowadays, the control of the pea moth *Cydia nigricana* (F.) is based on catches of pheromone traps (TUOVINEN 1982). Monitoring of the codling moth *Cydia pomonella* (L.) has been possible in practice since the beginning of 1980's (HEIKINHEIMO 1981). Studies on the use of pheromones for monitoring of several other pests occurring in orchards and berry plantations are being continued and some promising results have been achieved (PELTOTALO and TUOVINEN 1986).

Plant pests will not be eliminated

Substantial changes have taken place in our pest composition during the last hundred years. The worst scourge in the end of the 19th century and the first half of this century, the antler moth *Cerapteryx graminis* (L.), has become insignificant due to the development of grassland cultivation (VAPPULA 1962). The pest status of several insects, for example, the mustard beetle *Phaedon cochleariae* (F.) and the frit fly *Oscinella frit* (L.) has considerably declined, while that of others has increased. The rape blossom beetle *Meligethes aeneus* (F.), whose numbers have surprisingly proliferated, is the new pest of today and has begun to cause novel damages in cauliflower. The wheat blossom midge *Sitodiplosis mosellana* Geh. has caused severe destruction to wheat cultivations in southern Finland during the last few years. Finally, mention must be made of the western flower thrips *Frankliniella occidentalis* (Pergande) which is currently conquering Finland's greenhouses.

The frequency and abundance of plant diseases and weeds have also changed in many ways along with the progress made in cultivation.

The use of pesticides has not annihilated one single pest species, plant disease or weed to extinction in Finland or elsewhere. This clearly demonstrates the strong regenerative capacity of pests and that of nature in general.

By the present practice of pesticide application, it does not appear probable that populations of the natural enemies of pests would be permanently weakened or that the economic significance of pests would increase for that reason. However, the significance of predators and parasites must always be taken into account and attempts must be made to use pesticides in such a way as to spare the natural enemies.

However effective the control methods, in the future it will not be possible to finally eliminate the pests of plants. Insects, plant diseases and weeds will always plaque cultivated plants and be a source of problems to growers. Indeed, changes will occur in the composition of pest species and in the destructiveness of individual species, depending primarily on which plants are cultivated and what type of cultivation technique is employed. All cultivated plants have own special pests and the expension of the area under cultivation thus increases pest populations and increases the possibility of damages. The weather, too, will always have a considerable impact on plant diseases and on the occurrence of pests.

The continuous increase in international trade and traffic causes the danger that new pests, plant diseases and weeds will be carried to our cultivations from abroad. For this reason, the inspection of imported plants must be continuously maintained. Prevention is the most effective and inexpensive means of plant protection; however, the situation nowadays is nearly hopeless.

Chemical control dominates also in the future

Pesticide use has culminated in our country. The present choices of compounds and quantities used enables the control of nearly all plant diseases and pests. Applying more pesticides will not improve the economic result. Presently, research is being conducted into the possibilities for adjusting and decreasing the use of pesticides. Central to this process is the elucidation of the pest control as well as the development of prognose methods.

The use of herbicides has increased until recently, but it now appears that there is no longer any need to increase use. Suitable herbicides have been developed for almost all crops and growers are familiar with them.

The assortment of pesticides available is constantly changing, but in the future these changes may not be as rapid. The majority of the new compounds will also continue to be the synthetic products of the chemical industry. It is essential that these compounds are developed in such a way as to render them more effective than earlier, so that less chemical per unit area will be needed. Whereas nowadays most compounds — calculated as active ingredients — are sprayed in hundreds of grams per hectare, in coming decades the quantities applied will be limited to grams, i.e. to a hundredth of that at present.

There are some possibilities to discover compounds from wild plants possessing characteristics which kill or repel insects and are safe and effective enough to pass the tightening registration process. One good finding can lead to significant further developments.

The general trend will be toward pesticides that are safer to both users and to the environment yet at the same time their biological effectiveness and usability will be improved. In my view when research and the chemical industry designate the safety of compounds as their goal, they will succeed. The knowhow already exists and more knowledge is being gathered all the time.

Biological control will develop

It is my opinion that a considerable expansion of biological methods will take place for the control of plant diseases and pests. However, chemical control will not be displaced by alternative methods during the coming decades, except in special cases. Biological and other natural means of control cannot rapidly replace chemical control and perhaps never will.

The Agricultural Research Centre's Department of Pest Investigation continuously monitors the functioning and success of biological control in Finnish greenhouse cultivations. The goal is that parasites, predators, and diseases of control organisms will be discovered in good time. Such monitoring work will ensure the continual success of biological control for the worst pests of greenhouse cultivations.

The biological control of plant diseases in commercial greenhouse cultivations should begin within the next few years. On the basis of research conducted by the Department of Plant Pathology of the Agricultural Research Centre, an actinomycetes preparation which can be applied for the control of many seed and soil transmitted fungi should soon be introduced (e.g. TAHVONEN 1985, TAHVONEN and AVIKAINEN 1987). The debut of this Finnish preparation on the market will be among the very first preventive biopreparations against plant diseases.

The development of biological methods for pest control in outdoor cultivations is a difficult undertaking and good results cannot be promised in advance. All new biological preparations and methods developed abroad ought to be assessed by us. Promising products should be further investigated for use in Finland.

The Department of Pest Investigation has implemented an extensive project on microbiological control. Its central premise is to seek such fungi and parasitic nematodes from our soil which could be used for the control of insects on outdoor cultivations (e.g. HOKKANEN and ZIMMERMAN 1986). Diverse international expertise is a feature of the project.

Our country has not resorted to the use of classical biological control. No parasites of pests nor predators have been brought to Finland for introduction into our natural environment. Recently, interest in this old form of biological control has been renewed, however, and it might be worthwhile to experiment in Finland, too.

The alternatives are few

New synthetic feromones are being continuously developed abroad. Therefore developments in this field must be closely followed and all new preparations which would seem to be applicable to Finnish conditions ought to be obtained for experimentation.

The method using trap plants in the control of *Meligethes aeneus* could be further improved. The success of the cultivation of trap plants in the case of *M. aeneus* is chiefly based upon the yellow colour of the flowers. It is thus justified to investigate use of colours more broadly and integrate chemical and soft methods therein.

During the last few years the Department of Pest Investigation has investigated the use of various mechanical barriers in the control of pests that damage the root systems of plants (e.g. HAVUKKALA et. al. 1984). Good practical results have not been obtained and thus research has been interrupted at this stage.

Long-term research into use of companion plants — also termed mixed cropping — in pest control has not yielded results which would recommend widespread use of this method (e.g. MARKKULA and TIITTANEN 1982). Plants do not have sufficiently strong repellent features, nor does side-by-side cultivation reduce the amount of pests enough to eliminate the need for chemical control.

New soft technological methods by research

On the whole, in my opinion it is certain that by the continuation and expansion of research into soft methods, new means of control will be found which will be effective, economical and harmless to the environment. Investigations must be made separately for each pest species as the life cycles and damage patterns are rather diverse. Even if no economically competitive general solution cannot be found from the use of soft methods, as compared with pesticides, such methods can be more advantageous than chemical means in the control of certain species of plant pests and diseases.

In the next few years new biological methods will become available for use in the control of pests and plant diseases in greenhouses as well as outdoor cultivations.

Regular resistance testing for plant diseases should take place in connection with practical breeding work. Resistance breeding as such must be implemented also. The cultivation of resistant varieties can create a natural basis for plant protection and at the same time decrease the need for the use of pesticides. However, it must be remembered that the development of resistant varieties will take from 10 to 20 years, and that almost without exception, resistance is directed at one pest species only.

The possibilities of biotechnological application are mainly concerned with the development of resistant plants. The theoretical prospects are revolutionary, but practical applications will be possible only after decades.

The future control of weeds will almost exclusively be by chemical control. Old, mechanical methods employed in the past are too laborious and the implementation of new, soft methods which are sufficiently effective does not appear probable.

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Manuscript received May 1988

Martti Markkula
Agricultural Research Centre
Department of Pest Investigation
SF-31600 Jokioinen, Finland

SELOSTUS

Kasvinsuojelun nykytila ja lähiaikojen näkymät

MARTTI MARKKULA

Maatalouden tutkimuskeskus

Kemiallisessa torjunnassa on tultu lakipisteeseen. Runsaampi torjunta-aineiden käyttö ei enää paranna taloudellista tulosta. Nyt tutkitaankin mahdollisuuksia torjunta-aineiden käytön tarkentamiseen ja vähentämiseen.

Tuhoeläinten biologinen torjunta on ollut yleistä kasvihuoneviljelyksillä 1970-luvun alusta lähtien. Tupakkaripsiäisen torjunta ripsiäispunkin avulla on alkamassa kasvihuoneissa ja maahan äskettäin kulkeutuneen kalifornianripsiäisen biologisen torjunnan tutkimus on aloitettu.

Avomaan viljelyksille kehitellään biologisia torjuntakeinoja tuhoeläinten ja kasvitautien torjumiseksi. Useiden maalevintäisten ja siemenlevintäisten sienitautien torjunta alkanee lähivuosina sädesienipreparaattia käyttäen.

Bioteknologialta ja resistenssijalostukselta odotetaan uusia tuloksia, jotka ovat hyödynnettävissä käytännön kasvinsuojelussa.

Rikkakasvien torjunta hoidetaan tulevaisuudessakin miltei yksinomaan torjunta-ainein. Aineiden käyttömäärät pienenevät, mutta tehokkuus paranee. Haitattomuus ympäristölle otetaan torjunta-aineiden tarkastuksessa huomioon entistä vahvemmin.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 199—207 (1988)

Seria AGRICULTURA N. 90 — Sarja PELTOVILJELY n:o 90

THE CULTIVATION AND BREEDING OF OILSEED CROPS IN FINLAND

KATRI PAHKALA and MATTI SOVERO

PAHKALA, K. & SOVERO, M. 1988. **The cultivation and breeding of oilseed crops in Finland.** Ann. Agric. Fenn. 27: 199—207. (Agric. Res. Centre, Dept. Crop Sci., SF-31600 Jokioinen, Finland.)

INTRODUCTION

The actual cultivation and study of oilseed crops was started in Finland at the beginning of the 1940s, when their importation was interrupted due to World War II. Linseed, oilseed flax and some mustards were grown at first. In the beginning of the 1950s the cultivation of oilseed rapes was started, the first of these being winter turnip rape. The cultivated area of winter turnip rape rapidly expanded until 1958 when it comprised 18 600 hectares (HIIVOLA 1966). By 1976, the cultivation of biennial winter turnip rape had completely ceased in practice. In its place came low erucic varieties of annual spring turnip rape (*Brassica campestris*) and annual spring rape (*Brassica napus*). As quality improved, the domestic utilization of plant oil increased and led to the diversification of its use by the food processing industry. This, in turn, caused an expansion of the cultivated area of oilseed rape, as well as the intensification of research and breeding.

PRODUCTION OF ANNUAL OILSEED RAPE IN FINLAND

In 1987, the total cultivated area of spring sown oilseed crops was 82 000 hectares of which spring turnip rape comprised 96 % and the remainder being spring rape (Fig. 1). The total annual harvest has been 70—120 mil. kg. The oil obtained from the seeds is chiefly used by the food processing industry. It is also used for livestock feeds and for technical purposes such as in lubricants, for example. Approximately 21 mil. kg of rapeseed oil is exported yearly. Turnip rape and rape seeds contain 20—21 % protein which is both easily and profitably fortified into livestock feeds in concentrate form. The importance of these crops as sources of protein has increased, especially as the toxic glucosinolates, which previously restricted the use of these crops, have largely been successfully removed from present-day varieties.

In Finland, oilseed crops are mainly culti-

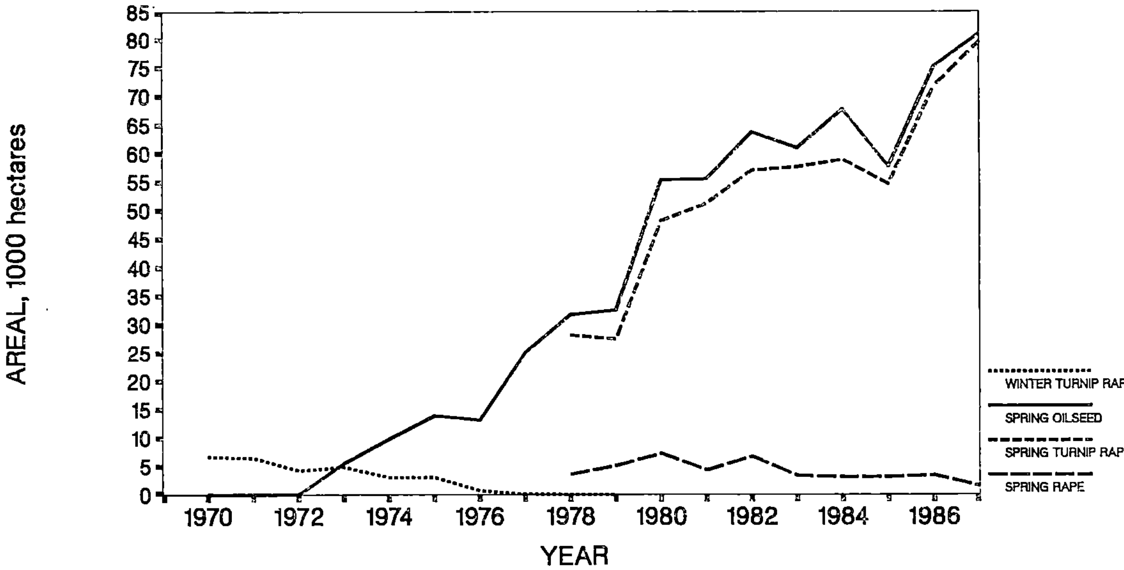

Fig. 1. Oilseed crops in Finland 1970—1987.

vated between the latitudes of 60° N and 62° N, and sometimes up to the latitude of 63° N. The world's northernmost turnip rape fields are found near Oulu. Spring rape is grown in the coastal areas of southern and southwestern Finland. In practice, oilseed crops are cultivated under contracts made between producers and oilfactories and the feed industry, or their authorized representatives. There are three oilfactories in Finland: the Hankkija oilfactory in Kouvola; the Raisio Group in Raisio; and, Öljynpuristamo Oy in Helsinki.

Research has been conducted on the cultivation of other oilseed crops such as mustard, poppy, sea kale, camelina, linseed, sunflower and evening primrose. The most successful crops have been the varieties of mustard (*Sinapis alba, Brassica juncea*), that are cultivated for oil and spice purposes. Production of the earliest varieties of poppy (*Papaver somniferum*), sunflower (*Helianthus annuus*), and linseed (*Linum usitatissimum*) has proved possible in southern Finland.

BREEDING OF OILSEED CROPS

Initially, the breeding of oilseed crops was practiced at the Agricultural Research Centre in conjunction with technical cultivation tests at the Department of Crop Science. Linseed var. Tikkurila originates from 1942 and is an earlier cultivar than imported cultivars. The Department of Plant Breeding began further breeding of annual oilseed rape in 1971. Previously, biennial winter turnip rape had been bred to some extent. Nowadays, the subject of breeding is mainly spring turnip rape. Spring rape, brown mustard, linseed and sunflower are bred in small quantities. The winter turnip rape var. Kulta (1973), the spring rape var. Alku (1975) and the spring turnip rape var. Nopsa (1986) have been put on the market

Table 1. Oilseed crops bred in Finland (VALLE 1953, MULTAMÄKI & KASEVA 1987).

	Variety	Year	Breeder
Brassica campestris			
Winter turnip rape	Kulta	1973	Jokioinen
Spring turnip rape	Hankkijan Simeoni	1975	Hankkija
	Hankkijan Vankka	1982	Hankkija
	Valtti	1985	Hankkija
	Nopsa	1986	Jokioinen
Brassica napus			
Spring rape	Alku	1975	Jokioinen
	Hankkijan Lauri	1975	Hankkija
	Varma	1985	Hankkija
Linum usitatissimum			
Linseed	Tikkurilan öljypellava	1942	Jokioinen

by the Department of Plant Breeding. In Finland, oilseed crops are also bred at the Hankkija Plant Breeding Institute. The Finnish oilseed varieties are presented in Table 1.

The most significant breeding targets have been high yielding capacity and seed quality with improved yield certainty. The specific objectives of quality breeding have been to increase oil and protein contents; decrease toxic compounds, such as glucosinolates; and, improve fatty acid composition to better meet the needs of industry.

Productivity increase

A considerable increase in productivity continues to be one of the chief goals in the breeding of oilseed rape. Currently, the main methods in rape productivity breeding are based on mass selection. The aim is to develop sufficiently uniform, productive and high quality cross-pollinating varieties.

Yield productivity in turnip rape has progressed slowly by traditional methods (Fig. 2). The transfer to hybrid varieties, for example, has been proposed as a solution to this problem, and preliminary studies have indicated these to be promising. They have also been demonstrated to tolerate environmental changes better than previous varieties.

One of the main problems in hybrid breeding is the regulation of pollination. In most agricultural plants, for instance, corn and sugar beet, cytoplasmic male sterility factors are used for this purpose. Genes producing cytoplasmic sterility as well as other genes which restore normal fertility in the actual hybrid are needed in order to use this method.

The possibilities for utilizing pol-cytoplasm from the rape in the production of turnip rape hybrid seeds have been studied at the Department of Plant Breeding. Both cytoplasmic sterility maintaining and fertility restoring factors have been found in turnip rape (Table 2). Cytoplasm has not been observed to have any yield lowering side effects in turnip rape as is sometimes the case with rape. Technically, the utilization of this system appears to be entirely possible.

The pedigree method is mainly used for the breeding of rape and other partly or totally self-pollinating oilseed crops. Thus, the varieties bred are nearly pure lines and hence are considerably more uniform than cross-pollinated varieties. Generally, the breeding of the yield has been rather successful for rape. However, changes in quality demands in the 1970s have constricted the genetic material useful to breeders.

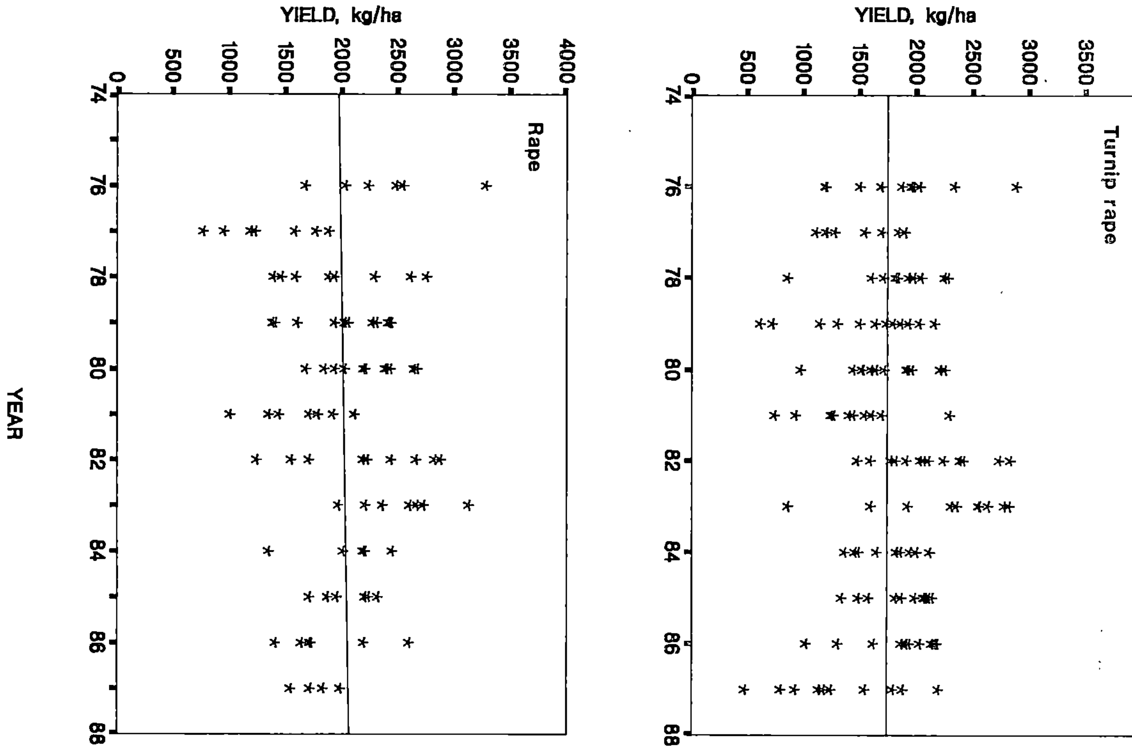

Fig. 2. Mean yields of spring turnip rape and rape from the official variety tests 1976—1987. Linear regression between the yield and the years: Turnip rape Y = 1794 - 0.634X, rsq = 0,000, p = 0.960
Rape Y = 1453 + 6.961X, rsq = 0.002, p = 0.685

Table 2. Male sterility and male fertility in the F1 generation of crosses involving male sterile *Brassica campestris* (pol) and strains and cultivars of spring turnip rape.

Cultivar	Country of origin	No. of crosses	No. of plants observ.	Male fertility of plants: Sterile	Part. Sterile	Fertile
Span	Canada	15	150	110	29	11
Tobin	Canada	25	247	140	82	25
Torch	Canada	22	212	173	35	4
Nopsa	Finland	27	265	117	85	63
BSH-1	India	28	277	237	13	27
Pusa Kalyani	India	24	234	222	12	0
Ante	Sweden	20	191	82	27	82
Emma	Sweden	19	186	100	42	44
Torpe	Sweden	21	199	135	40	24
Tyko	Sweden	19	187	118	57	12

Haploid breeding is a relatively new method for the breeding of oilseed crops. By this method, a generation of homozygote plants can be produced in less than one year. By combining both haploid production and natural variation in cell tissue culture it is possible to biotechnically produce diversified homozygous material which can be further utilized in breeding (SORVARI 1985).

Quality breeding

Changes in quality requirements and the withdrawal of high erucic varieties of oilseed rape from cultivation have caused problems. The new type of rapeseed oil mainly contains fatty acids with carbon chains of 18 atoms. This uniform composition leads to crystallization of the oil, and margarine manufactured from this type of oil has an unpleasant granular structure. In addition, because linolenic acid contains three double bonds and therefore oxidizes readily the high proportion of linolenic acid in the oil increases the tendency of the oil to turn rancid.

It is possible to further improve the quality of low erucic oil obtained from cruciferous crops by plant breeding. A part of the plant fats presently imported could then be compensated by domestic production. At the Department of Plant Breeding, breeding for oil quality has focused on the low erucic types of turnip rape, rape and brown mustard. At present, the main emphasis of this work is to alter the levels of palmitine and linolenic acid. An increase in the proportion of palmitic acid, whose carbon chain is only sixteen atoms long, would decrease crystallization in rape oil and thus improve its usability in the margarine industry. Lowering the linolenic acid level, however, would decrease the tendency of the oil to turn rancid, which would be advantageous to all food oils. Another objective of breeding has also been that of varieties with exceptionally high levels of either oleic acid or linoleic acid. One of the possible new fields is also the breeding of such varieties whose oil could be utilized for technical purposes. The ranges of different fatty acid levels in our breeding material are presented in Table 3.

Table 3. Variation in levels of the most important fatty acids in the Department of Plant Breeding's winter turnip rape, rape and brown mustard breeding material.

Species	Palmitic acid*	Oleic acid*	Linoleic acid*	Linolenic acid*	Erucic acid**
Turnip rape	1.1—16.5	17.5—74.3	10.0—41.2	3.5—29.5	66.0
Rape	2.2—16.0	33.0—77.4	9.9—41.2	2.1—16.6	—
Brown-mustard	2.8— 5.0	38.9—50.0	26.8—41.7	9.7—18.3	43.6

* Ranges of levels in erucic acid-free material
** Maximum level in high erucic material

Protein breeding

The quality of protein obtained from oilseed crops is good, being nearly the best available vegetable protein. One of the main subjects of breeding is to increase the protein content of the yield. The aim is to obtain the highest possible utility yield, i.e. a high combined level of both protein and oil. Protein content has not been selected separately, because exceptionally high protein percentages are often linked to a low yield.

The Department of Plant Breeding transferred to the breeding of the low glucosinolate two-zero variety of spring turnip rape and rape at the end of the 1970s, and a similar transfer is now in progress also for biennial winter turnip rape. At the moment, there is no really low glucosinolate material available from brown mustard. The lowering of glucosinolate level and modification of its chemical composition is being studied because brown mustard is being bred primarily as an oil and protein crop by the Department of Plant Breeding.

PRESENT-DAY CULTIVATION TECHNIQUES

Turnip rape is sown during the second or third week of May. In southern Finland the average sowing date is May 17th. The field ploughed in the previous autumn is harrowed 1—2 times and sown with a fertilizer spreader by which the fertilizer is placed close to the row sown. Rows are spaced at 12.5 cm and sowing depth is about 3 cm. The fertilizers are compound products containing trace and side nutrients in addition to the main nutrients. Fertilizers are selected according to soil potassium and phosphorous status. Nitrogen amount is about 80—120 kg/ha. Promising experimental results have been obtained with growth regulators. However, their use has not been officially approved, yet.

The seeds for sowing are delivered to the growers as predressed or coated. Seed dressing controls the damage caused by flea beetles (*Phyllotreta* spp.) during the cotyledonous stage. Blossom beetle (*Meligethes aeneus*) is controlled, as needed, by a proper insecticide 1—2 times before flowering. Synthetic pyrethroids are the most common insecticides used. For the control of broad leaved weeds, 23 % of the oilseed area was sprayed with herbicides in 1987; the respective figure for grass weed control was 22 %. The most harmful weed species are couch grass and wild oats. During the rainy years of 1984 and 1987, plant diseases caused great damage locally. The most common diseases in rapeseed samples collected after flowering have been stem rot caused by *Sclerotinia sclerotiorum*, greymold caused by *Botrytis cinerea*, downy mildew caused by *Peronospora parasitica*, clubroot caused by *Plasmodiophora brassicae*, and stem base lesions caused by *Rhizoctonia solani* (HANNUKKALA 1988).

Oilseed crops are harvested with a combine when the plant stand has sufficiently ripened. The yield is dried by special oil heated grain drier on the farm to 7—9 % moisture and delivered to the buyer either immediately or later in the winter.

A source of problems in the cultivation of oilseed crops is the creation of a sufficiently even plant stand. The germination of seeds and emergence of plants is deficient during dry springs and the damage by pests is greater, too. On the other hand, abundant vegetative growth and lodging of the stems during rainy years may considerably increase plant diseases and weed problems. If the sowing of oilseed crops is not completed on time, threshing is delayed to late autumn when the weather is usually rainy. The high moisture content of the seeds causes injuries during threshing. Weed problems may arise when rape seeds get spread over the field before or in connection with threshing.

CULTIVATION REQUIREMENTS AND LIMITING FACTORS

Spring oilseed crops are well adapted to our selection of cultivated plants despite the fact that they are at their extreme border of cultivation. Regardless of the rather considerable annual variation in yield, no total crop failure has occurred with spring sown oilseed crops throughout the period of continuous cultivation which began in 1976. Turnip rape ripens and produces a satisfactory yield both during cool and rainy summers. It is able to advantageously utilize the great amount of radiation during early summer provided that the minimum temperature is not too low. The effective temperature sum required for the ripening of spring turnip rape varies each year (Fig. 3). The experiences of 1987, however, showed that turnip rape will ripen even if the effective temperature sum is 817 °C from sowing to harvest time which is 172 °C below normal. Instead, in the case of rape, cool summers cause substantial losses in quality and yield as its growing period in Finland is approximately two weeks longer than that of turnip rape.

With regard to yield formation, favourable weather factors include high temperatures just before sowing, high levels of radiation at the end of flowering and at the start of pod development. Bright, cool weather at the end of ripening and during harvesting ensures successful threshing. Detrimental factors are heavy rains after emergence and during the vegetative stage. A deficiency of water at the end of flowering and beginning of pod development, decreases yield. Cool weather during autumn lengthens the development time of pods and increases yield (PAHKALA et al. 1987).

According to official variety tests carried out at several research stations, the best yields are obtained from clay and silt soils. The difference compared to coarse mineral soils is 5—12 %. This is due to the better water and nutrient balance of clay soils. There are few experimental results on the cultivation of oilseed crops in peat soils. Practical cultivation experiences with peat soils have proved successful in good years. During rainy and cold summers, however, the ripening of the crop is delayed and plant diseases poses a threat.

Acknowledgements — The authors wish to thank Professor Jaakko Mukula and M. Sc. Juha Vilkki for comments on the manuscript.

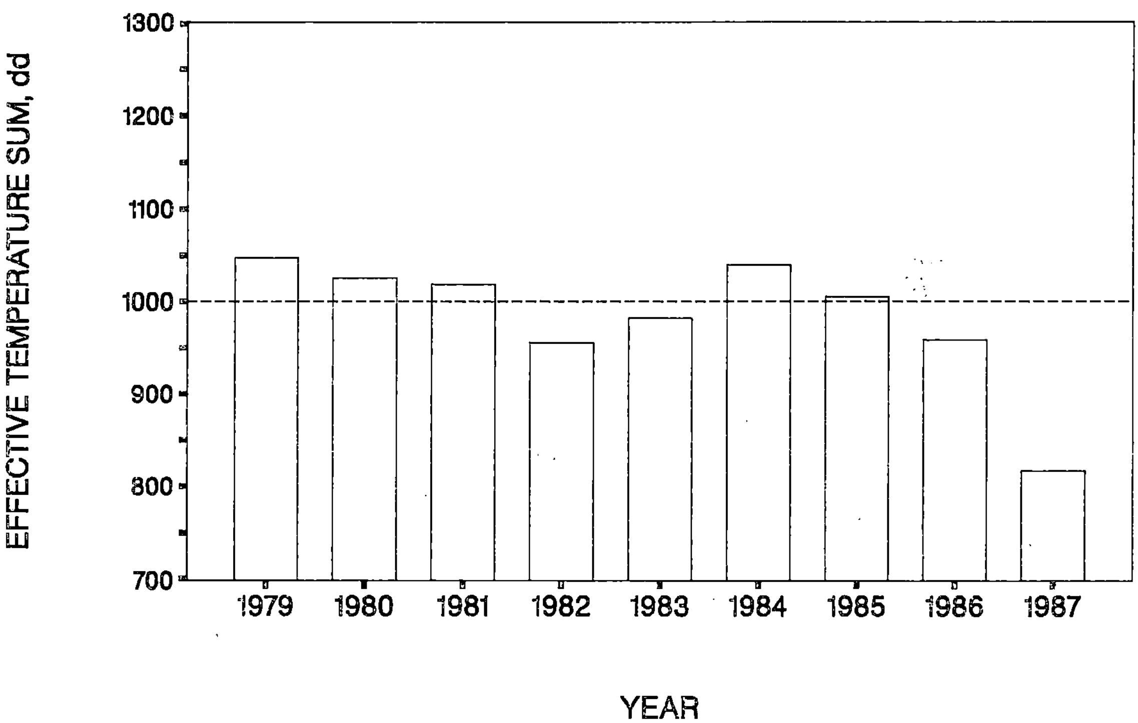

Fig. 3. Effective temperature sum (>5 °C) for the ripening of spring turnip rape varieties Ante, Emma and Span. Official variety tests 1979—1987.

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Manuscript received March 1988

Katri Pahkala
Agricultural Research Centre
Department of Crop Science
SF-31600 Jokioinen, Finland

Matti Sovero
Agricultural Research Centre
Department of Plant Breeding
SF-31600 Jokioinen, Finland

SELOSTUS

Öljykasvien viljely ja jalostus Suomessa

KATRI PAHKALA ja MATTI SOVERO

Maatalouden tutkimuskeskus

Öljykasvien viljely ja tutkimus aloitettiin Suomessa 1940-luvun alussa. Aluksi viljeltiin öljypellavaa, kuituöljypellavaa ja hiukan keltasinappia. *Brassica*-suvun öljykasveista alettiin ensimmäiseksi viljellä syysrypsiä 1950-luvun alussa. Syysrypsin viljelyala laajeni nopeasti aina vuoteen 1959 saakka, jolloin se oli 18 600 hehtaaria. Vuoteen 1976 mennessä syysöljykasvien viljely loppui ja tilalle tulivat kevätrypsi (*Brassica campestris*) ja kevätrapsi (*Brassica napus*), joista oli saatavana elintarviketeollisuuden vaatimusten mukaisia, matalaerukkaisia lajikkeita. Laadun parantuessa kotimaisen kasviöljyn käyttö lisääntyi ja monipuolistui teollisuudessa, mikä aiheutti öljykasvien viljelyalojen moninkertaistumisen. Vuonna 1987 kevätöljykasveja viljeltiin 82 000 hehtaarilla.

Siemenistä saatava öljy käytetään elintarvikkeisiin, karjan rehuihin ja teknisiin tarkoituksiin. Vuosittain viedään ulkomaille noin 21 milj. kg kotimaista kasviöljyä. Rypsin ja rapsin merkitys proteiinin tuottajina on lisääntynyt, sillä aikaisemmin käyttöä rajoittaneet haitalliset glukosinolaatit on onnistuttu suurelta osin poistamaan nykyisistä lajikkeista.

Rypsiä ja rapsia viljellään Suomessa leveysasteiden 60° N ja 62° N välillä, satunnaisesti 63° N leveysasteelle saakka. Maailman pohjoisimmat rypsiviljelykset löytyvät Oulun läheltä. Kevätrapsia viljellään rannikkoseudulla Etelä- ja Lounais-Suomessa. Muista öljykasvilajeista parhaiten ovat menestyneet keltasinappi (*Sinapis alba*) ja Sareptan sinappi (*Brassica juncea*), joita on viljelty öljy- ja maustetarkoituksiin. Unikon (*Papaver somniferum*), auringonkukan (*Helianthus annuus*) ja öljypellavan (*Linum usitatissimum*) aikaisimpien lajikkeiden viljely on mahdollista Etelä-Suomessa.

Kevätöljykasvit ovat sopeutuneet viljelykasvivalikoimaamme hyvin. Ne tuleentuvat ja tuottavat satoa myös viileinä ja sateisina kesinä. Ne pystyvät hyödyntämään alkukesän suuren säteilymäärän, jos öisin ei esiinny halloja. Kuivina keväinä saattaa esiintyä ongelmia riittävän tasaisen kasvuston aikaan saamisessa, kun taimettuminen on puutteellista ja tuholaisten aiheuttamat vioitukset suurempia. Toisaalta taas sateisina vuosina kasvustojen rehevyys ja lakoutuminen aiheuttavat huomattavan kasvitautiriskin.

Öljykasveja jalostettiin Maatalouden tutkimuskeskuksessa aluksi viljelyteknisten kokeiden ohella kasvinviljelyosastolla. Vuodelta 1942 onkin peräisin ulkomaisia lajikkeita aikaisempi Tikkurilan öljypellava. Kasvinjalostusosasto aloitti kevätöljykasvien jalostuksen vuonna 1971. Sitä ennen oli jossain määrin jalostettu syysöljykasveja. Nykyisin jalostetaan pääasiassa kevätrypsiä ja -rapsia.

Jalostettavista ominaisuuksista tärkeimpiä ovat korkea laatu, satoisuus ja viljelyvarmuus. Laadun jalostuksen tavoitteena ovat sadon öljyn ja proteiinin yhteispitoisuuden nostaminen ja haitallisten aineiden — esim. glukosinolaattien vähentäminen. Tärkeänä on pidetty myös öljyn rasvahappokoostumuksen muokkaamista paremmin teollisuuden tarpeita vastaavaksi jalostamalla esimerkiksi matalalinoleenisia kantoja. Rypsin satoisuusjalostuksessa on perinteisten, massavalintaan perustuvien menetelmien lisäksi tutkittu mahdollisuuksia tuottaa hybridilajikkeita. Rypsin jalostuksessa on hyödynnetty myös bioteknisiä menetelmiä kuten haploidijalostusta. Rapsia ja muita osittain tai kokonaan itsesiittoisia öljykasveja jalostetaan pääasiassa pedigree-menetelmällä.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 209—218 (1988)

Seria PHYTOPATHOLOGIA N. 106 — Sarja KASVITAUDIT n:o 106

PRODUCTION OF HEALTHY PLANTING MATERIAL

MARJATTA UOSUKAINEN and AARNE KURPPA

UOSUKAINEN, M. & KURPPA, A. 1988. **Production of healthy planting material.** Ann. Agric. Fenn. 27: 209—218. (Agric. Res. Centre, Healthy Plant Center, SF-41340 Laukaa, Finland.)

In Finland the production of healthy planting material was started on regular bases in 1977. In the Finnish production scheme nuclear stock is introduced and elite stock is produced in cooperation of four research units at the Agricultural Research Centre. Certified stock is produced only from the most important small fruit species by 31 special commercial nurseries under inspection of the National Board of Agriculture. In Finland, about 90 % of all sold strawberry plants, 25 % of black currant and 50 % of sold raspberry plants were certified stock in 1986. Elite stock of other species is available for all registered nurseries.

In introduction of nuclear plants at the Department of Plant Pathology, thermoterapy, combined use of thermoterapy and apical meristem culture and meristem culture alone were used for disease elimination. At preliminary testing for diseases and pests has been used ELISA, electron microscopy and herbaceous tests plants. Besides them, immunoelectron microscopy, extraction and fractionation of viral double-stranded RNA and sensitive both herbaceous and woody indicator plants has been used for the final testing of the nuclear plant candidates.

By the end of 1987 elite stock was available from strawberry (10 cultivars), raspberry (5), black (5), red (5), white (3) and green (1) currant, gooseberry (3), black chokeberry — *Aronia melanocarpa* (1), highbush blueberry — *Vaccinium* sp. (1), arctic bramble — *Rubus arcticus* (4), *Potentilla fruticosa* (6), ornamental *Ribes*- species (2). In the process of disease elimination there were six *Malus*, two *Hippophae rhamnoides*, three *Phlox paniculata* and one *Prunus domestica* cultivars.

Index words: antiviral agents, apple, certified stock, elite stock, healthy planting material, meristem culture, nuclear stock, perennial ornamentals, small fruit, thermoterapy, tissue culture, virus elimination, virus testing, woody ornamentals.

INTRODUCTION

In 1960's small fruit growing started to become an important alternative to traditional agriculture in Finland. The culture areas became larger but the yields per hectare remained low. Profitability of small fruit growing was not as expected. Among growers and government authorities there rose a great concern about constant confusions in cultivars and the low sanitary status of nursery produced small fruit plants. Lack of high quality, healthy planting material was regarded as the major factor that prevented economically efficient small fruit production in Finland.

Discussions about how to arrange the production of genetically true-to type and virus-free planting material were started as early as in 1960 (LARSSON and LOKONEN 1983). During the next thirteen years several more or less succesful minor trials were done in introduction and production of healthy small fruit plants. Finally, in 1973, the SITRA-fund started to finance a large scale research program in order to develop production methods both for elite stock and for certified stock of small fruit species. The research program ended in 1975. On the research report's recommendation, the Ministry of Agriculture and Forestry gave to the Agricultural Research Centre the task to organize and start the introduction and production of high quality propagation material of horticultural plants. The Healthy Plant Center was founded in 1976 to carry out this task at the Agricultural Research Centre.

PRODUCTION METHODS

The production method in Finland was originally based on the Norwegian production scheme. The leading principle was, that the production of elite stock at the Agricultural Research Centre should be economically profitable. This principle was also the quide line for the Swedish authorities, when the production scheme of healthy plants was planned in Sweden in early 1980's (SILVER, 1985). In Finland however, it soon became obvious that introduction and production of nuclear and elite stock must be in high grade dominated by research work. Therefore the demand for profitability was deleted at the beginning of 1988. The Finnish production scheme (Fig. 1). resembles to day much the Danish model.

Nuclear stock

The nuclear stock is introduced in cooperation with four research units at the Agricultural Research Centre. The Department of Horticulture breeds and selects cultivars and nuclear plant candidates. The Department of Plant Pathology and the Department of Pest Investigation do virus and pest elimination and testing for the nuclear stock candidates. At the Healthy Plant Center the nuclear stock is retested and if needed, disease elimination is continued. The nuclear stock is maintained at the Healthy Plant Center either *in vivo* in greenhouses or *in vitro*.

At the Department of Plant Pathology research for obtaining healthy nuclear stock to be further maintained and propagated at the Healthy Plant Center at Laukaa has been continued over ten years. During this time nuclear stock from all major small fruit species has been released. During the past six years much effort is put to virus elimination of new Finnish apple cultivars (LEMMETTY 1987). The first woody ornamentals were taken into production over five years ago. The available nuclear stock and the material which is under disease elimination are listed in Tables 1, 2 and 3.

Elite stock

At the Healthy Plant Center elite stock is propagated from the nuclear stock. Elite stock is sold to commercial nurseries. The regular propagation of elite stock from small fruit species was started in 1977. During that year a

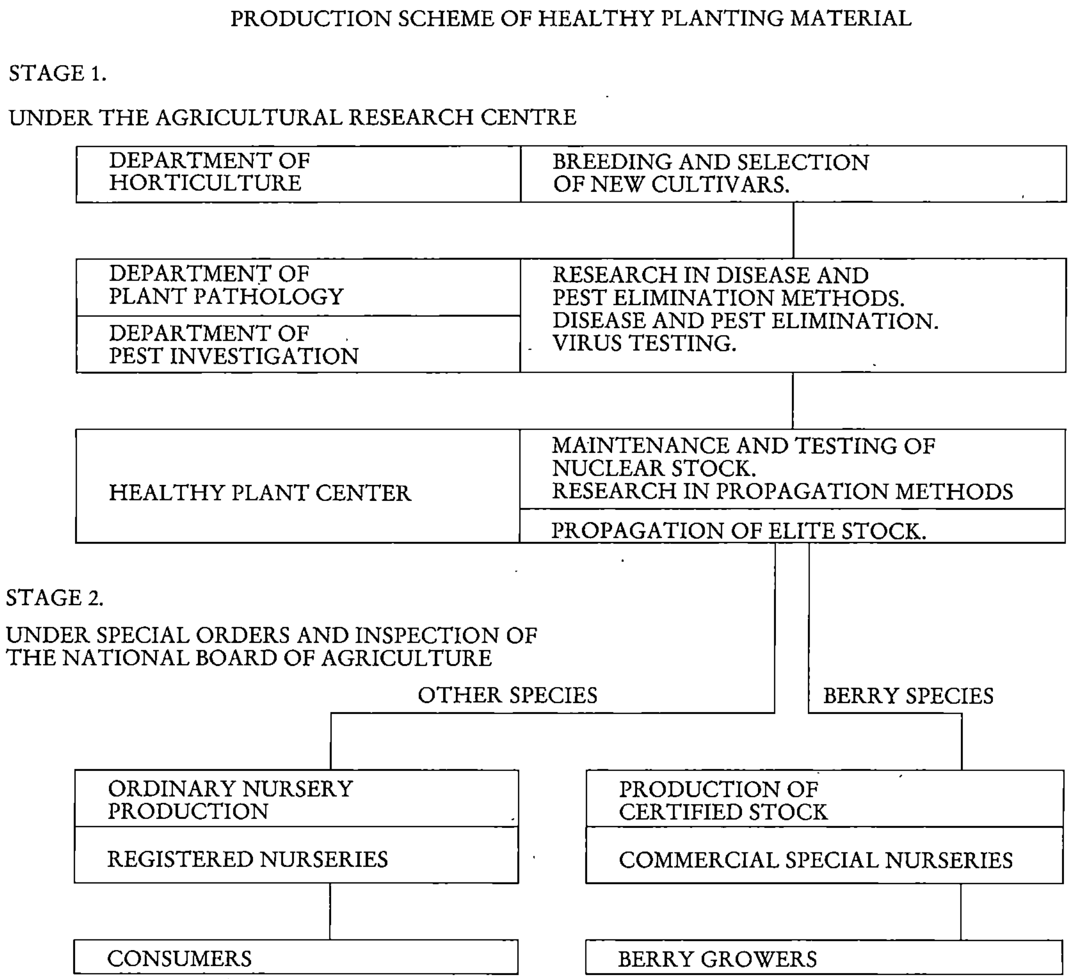

Figure 1. The production scheme of healthy planting material at the Agricultural Research Centre and the production of certified stock and other high quality planting material.

total of 4 775 elite plants were sold. In 1985 a total of 52 057 plants and in 1987 a total of 146 407 elite plants were sold. The development of elite stock production is presented in Table 4.

Between 1976—1984 the development in elite stock production was slow. The cause for slow development was lack of premises at the Healthy Plant Center. After new offices, laboratories and greenhouses were completed in 1985 the elite stock production could reach the production level that was needed.

Certified stock

Certified stock is produced from the economically most important small fruit species; strawberry, raspberry, currants, gooseberry and in the future also from apple cultivars. The elite stock is therefore sold only to special commercial nurseries approved by the National Board of Agriculture. The producers of certified stock are obliged to follow orders and instructions from governmental authorities and inspectors

Table 1. Virus-free nuclear stock species and cultivars for certified stock production.

SPECIES	CULTIVAR AND/OR ORIGIN
STRAWBERRY (*Fragaria* × *ananassa*)	'Senga Sengana' (Norway) 'Jonsok' (Norway) 'Hiku' (Piikkiö) 'Kristina' (Sweden) 'Zefyr' 'Ostara' 'Alaska Pioneer' (Viikki) 'Mari' (Piikkiö)
RED RASPBERRY (*Rubus idaeus*)	'Muskoka' 'Ottawa' 'Preussen' 'Ville' (Piikkiö)
(*Rubus* × *binatus*)	'Heisa' (Piikkiö)
BLACK CURRANT (*Ribes nigrum*)	'Öjebyn' 'Melalahti' 'Imandra' 'Brödtorp' 67008081 (Piikkiö)
GREEN CURRANT (*Ribes nigrum*)	'Vertti' (Piikkiö)
RED CURRANT (*Ribes rubrum*, *Ribes pallidum*)	'Red Dutch' (Piikkiö) 'Rondom' 'Roteswunder' 'Traubenwunder' 'Jonkher van Tets' (Tikkurila)
WHITE CURRANT (*Ribes rubrum*, *Ribes pallidum*)	'White Jutterbog' 'White Dutch' (Piikkiö) 'White Dutch' (Hämäläinen)
GOOSEBERRY (*Ribes uva-crispa*)	'Lepaa red' 'Hinnonmäki yellow' 'Hankkijan Herkku'

Table 2. True-to-type and virus-tested nuclear stock species and cultivars for uncertified nursery production.

SPECIES	CULTIVAR AND/OR ORIGIN
ARCTIC BRAMBLE (*Rubus arcticus*)	'Pima' (Karila) 'Mespi' (Karila) (pollination)
(*R. arcticus subsp.* × *stellarcticus*)	'Aura' (Piikkiö) 'Astra' (Piikkiö) (pollination)
BLACK CHOKEBERRY (*Aronia melanocarpa*)	'Viking' (Viikki)
HIGHBUSH BLUEBERRY (*Vaccinium uliginosum* × *V.* 'Rancocas')	'Aron' (Piikkiö)
STRAWBERRY (*Fragaria vesca* × *F. v.* var *semperflorens*	'Minja' (Piikkiö)
BUSH CINQUEFOIL (*Potentilla fruticosa*)	'Goldfinger' (Piikkiö) 'Goldteppich (Piikkiö) 'Månelys' (Piikkiö) 'Katherine van Dykes' (Piikkiö) 'Primrose Beauty' (Piikkiö) 'Sandved' (Piikkiö)
ALPINE CURRANT (*Ribes alpinum*)	(Kuopio)
GOLDEN CURRANT (*Ribes aureum*)	(Saarioinen)

Table 3. Species and cultivars in disease elimination.

SPECIES	CULTIVAR AND/OR ORIGIN
APPLE	'YP'-rootstock (Piikkiö) 'Jaspi' (Piikkiö) 'Maikki' (Piikkiö) 'Make' (Piikkiö) 'Pirja' (Piikkiö) 'Samo' (Piikkiö)
BUCKTHORN (*Hippophae rhamnoides*)	Female clone 72004004 (Piikkiö) Male clone 74006004 (Piikkiö)
BUSH CINQUEFOIL (*Potentilla fruticosa*)	'Jackman'
GARDEN PHLOX (*Phlox paniculata*)	'Frau Anthony Buchner' 'Spitfire' 'Wilhelm Kesselring'
PLUM (*Prunus domestica*)	'Sinikka'

from the National Board of Agriculture. The nurseries are inspected 1—2 times per year.

When the production was started a group of voluntary nursery growers were interested in the new production method and were willing to test it in co-operation with the Department of Plant Pathology. At the beginning 15 voluntary nurseries started the production of strawberry, raspberry and black currant. At the beginning of 1988 the number of producers was 31.

Table 4. Elite stock production of the Healthy Plant Center in 1977, in 1985 and in 1987.

SPECIES	YEAR 1977	1985	1987
Currants and gooseberry	297	2 963	5 581
Strawberry	4 060	41 975	127 420
Raspberry	418	4 757	4 395
Arctic bramble	—	605	2 733
Black chokeberry	—	1 340	5 276
Highbush blueberry	—	—	634
Woody ornamentals	—	417	368
Total	4 775	52 057	146 407

Other true-to-type virustested propagation material

Other elite stock is sold to all registered nurseries. Their production is not particularly inspected or ruled by the governmental officers. The main principle is to guarantee a possibility for the nurseries to obtain true-to-type mother stock. It depends on the growers how often they renew their mother plants.

DEVELOPMENT IN PRODUCTION

Although the number of sold healthy planting material is not published separately, the National Board of Agriculture has compiled statistics on the sales of certified stock (RUOTSALAINEN 1988). According to the statistics (Table 5) the sale of certified strawberry stock has grown very fast during the past three years. In 1987 the sale was almost 3.5 millions plants which covers about 90 % of all sold strawberry plants in Finland.

Marketing of other small fruit species has met with great difficulties instead. This is due to the hard competition in nursery production between relatively expensive, healthy planting material and the cheeper, normally produced, uncertified planting material. In Finland there are no limitations to prevent marketing of uncertified planting material. Although, within next three years there can be expected a rapid growth also in the production of certified currant planting material, when the two most important berry plant nurseries start the production of certified stock.

Table 5. Number of certified stock sold in Finland between 1977—1987.

YEAR	STRAWBERRY	RASPBERRY	CURRANTS AND GOOSEBERRY
1977	568 500	23 922	10 269
1978	1 200 129	38 300	42 015
1979	2 150 429	30 806	47 160
1980	2 514 783	44 178	76 112
1981	2 291 245	71 276	124 309
1982	2 096 315	72 458	160 564
1983	2 451 945	103 343	196 991
1984	2 589 614	78 375	117 621
1985	2 644 131	62 986	137 409
1986	3 396 889	86 305	147 857
1987	3 346 244	76 481	126 015

MICROPROPAGATION

Micropropagation in production

From the very beginning, micropropagation has played a very important role in Finnish healthy plant production. Meristem culture method was used in the production of nuclear stock already in 1970's (BREMER and KORHONEN 1978, BREMER 1983). Step by step micropropagation method was first applied in the nuclear plant production and since 1982 in elite stock production (UOSUKAINEN 1986). In 1988 all elite stock of strawberry, highbush blueberry, arctic bramble, gooseberry and plum are micropropagated.

In Finland, micropropagation technique was taken to use in early 1980's in commercial flower production. In 1986 the first commercial laboratory was allowed to start the production of certified strawberry plants. In 1987 there were two commercial laboratories that produced micropropagated certified stock directly for smallfruit growers (RUOTSALAINEN 1988).

Research in micropropagation techniques

The intention has been that the new species in elite stock at the Healthy Plant Center would mainly be micropropagated. Therefore the research activity in the field of tissue culture has an important role in horticultural research at the Agricultural Research Centre. During the past few years much effort has been put into the research of micropropagation methods of woody plants (UOSUKAINEN and NISKANEN 1985, UOSUKAINEN 1987).

At the Department of Plant Pathology much research has been done in the micropropagation techniques of new apple varieties. The research work at the Healthy Plant Center has been concentrated on micropropagation of following woody and perennial ornamentals: *Forsythia ovata*, *Hippophae rhamnoides*, *Hydrangea heteromalla*, *H. paniculata*, *Philadelphus*-hybrid, *P. coronarius*, *P. lewisii*, *P. pubescens*, *Phlox paniculata*, *Prunus domestica*, *Rosa pimpinellifolia* and *Vaccinium*-hybrid. A new tissue culture laboratory has also been established at the Department of Horticulture. The main interest there has been in families *Berberis*, *Forsythia*, *Fragaria*, *Hydrangea*, *Lonicera*, *Malus*, *Philadelphus*, *Prunus*, *Pyrus* and *Viburnum*.

DISEASE ELIMINATION

Vegetatively propagated plants of small fruits, fruit trees and perennial ornamentals are commonly infected with viruses or viruslike organismes e.g. viroids or MLO's. Also bacteria may cause latent infection in many cases.

Thermotherapy has been succesfully applied for the elimination of viruses and viruslike organismes in different crop plant species (KASSANIS 1954, BAKER 1962, NYLUND and COHEEN 1969). This method has been of practical value, not only as used alone for disease elimination, but also when used combined with tissue culture techniques. The methods used at the Agricultural Research Centre, Department of Plant Pathology, to produce virus-free nuclear plants are principally based on the combined use of thermotherapy and apical meristem culture (BREMER 1983, LEMMETTY 1987). Healthy black and red currants are produced by heat treatment alone but in the case of gooseberries, raspberries and strawberries, thermotherapy is combined with tissue culture.

Typically heat treatment is given to the vigorous selected plants growing in clay pot. The temperature in the growing chamber is raised gradually to approx. 37 °C and kept constant 3 to 8 weeks depending on the crop. Longer treatment is necessary for woody species. After the treatment, small cuttings are taken and rooted in the soil.

At present, apical meristem culturing is used to replace or supplement thermotherapy whenever possible. Production of healthy nuclear plants from cultivars of strawberries, gooseberries and raspberries has been greatly assisted by the use of tissue culture techniques. Also a number of perennial ornamental plant species could be obtained free of pathogens with combined thermotherapy and tissue culture. The growing media used for these purposes are basicly quite similar to one introduced by MURASHIGE and SKOOG (1962) with minor modifications in nutrient and hormone concentrations. For woody species various more or less different media have been developed (ANDERSON 1980, LLOYD and MCCOWN 1980, WELANDER 1985). Growing conditions too, have to be adjusted depending on the plant species.

Tissue culture of new Finnish apple varieties bred by the Department of Horticulture at Piikkiö, has met with difficulties because of very poor and variable rooting properties in the culture media. Complitely developed rooted plants has been obtained from 'Maikki', but in the other cases, the candidates for nuclear plants have been obtained from 'Maikki', but in cultured shoots to rootstock from seeds.

In addition to the techniques in producing of healthy nuclear plants, studies of the use of antiviral agents are in progress. Promising results concerning their effect on the viruses have been reported by e.g. CASSELS (1983) and HANSEN and LANE (1985). Until now our experience has not been that positive but experiments will be continued.

DISEASE TESTING OF NUCLEAR PLANT CANDIDATES

Preliminary testing for diseases and pests in the starting material has been applied increasingly over the years. Only relatively rapid test methods such as the ELISA, electron microscopy and herbaceous test plants are used at this step. This testing, however, gives some information about the material as well of expectations for the final tests after the disease elimination. Detection of latent bacteria in plant tissue could be achieved using a series of bacteria-favouring media during tissue culture steps.

For the final testing of the nuclear plant candidates for viruses and viruslike organisms, several different test methods need to be applied. For rapid detection double-sandwich ELISA (CLARK and ADAMS 1977), electron microscopy or immunoelectron microscopy and fractionation of viral double-stranded RNA (KURPPA and MARTIN 1986) and herbaceous test plant species are used. The woody species of small fruits and fruit trees, which have found to be healthy in the rapid tests, will also be tested with sensitive woody indicator plants. For the species and varieties used in each case, see the list below.

Apple:	*Malus pumila* cvs	Cox Orange Pippin Golden Delicious Lord Lambourne Spy 227 R 12740-7A Virginia Crab
	Malus platycarpa	
Currants and gooseberries:		
	Ribes nigrum cvs	Amos Black Baldwin Öjebyn
	Ribes grossularia cv.	Kaunisrannan punainen
Red raspberries and arctic bramble × Red raspberries:		
	Rubus idaeus cvs	Malling Delight Malling Landmark Norfolk Giant
	Rubus occidentalis cv.	Cumberlain

In addition to woody plant species also strawberry is tested with the indicators. The following strawberry varieties or clones are used for the tests in the leaf-grafting technique:

Fragaria vesca	EMK
	Fv-72
	UC-2, UC-5, UC-6
	VS-1

FUTURE STRATEGIES IN THE PRODUCTION OF HEALTHY PLANTING MATERIAL

An interview among small fruit growers, nurserymen, authorities and advicers revieled a general satisfaction to the production of healthy plant material. Increasing research activity in the field of biotechnology has already led to commercial application of micropropagation techniques in Finnish horticultural production. It seems clear that biotechnology will be increasingly applied in the production of healthy planting material of vegetatively propagated species. Tissue culture techniques has already reached nursery growers and in near future much planting material will be sold as test tube plantlets or potted plants which have never touched open field soil.

The selection of small fruits, fruit trees and ornamentals will be wider in the future. Some speciality crops will also be available. As the whole, the process of producing healthy planting material at the Agricultural Research Centre will include more research in the future than it does today. Instead of producing high quantities of potted elite stock, smaller stock groups of increasing number of cultivated and ornamental plant species and cultivars will be handled and maintained. Most of the propagation processes of high quality planting material will be done by selected nurseries.

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Manuscript received

Marjatta Uosukainen
Agricultural Research Centre
Healthy Plant Center
SF-41340 Laukaa, Finland

Aarne Kurppa
Agricultural Research Centre
Department of Plant Pathology
SF-39600 Jokioinen, Finland

SELOSTUS

Terveen taimiaineiston tuottaminen

MARJATTA UOSUKAINEN ja AARNE KURPPA

Maatalouden tutkimuskeskus

Kasvullisesti lisättävien puutarhakasvien terveiden ja aitojen taimien tuottaminen käynnistyi Suomessa 1970-luvun alkupuolella. Vuonna 1973 alettiin SITRA:n rahoituksella tutkia ja kehittää menetelmiä marjakasvien terveiden taimien tuottamiseksi. Viljeltyjen marjakasvien heikon satotason oli todettu johtuvan pääasiassa kasvustojen taudeista ja tuholaisista. Erityisesti kasvullisesti lisättyjen taimien mukana leviävät virustaudit alentavat pysyvästi sekä marjakasvien satoa että sadon laatua.

Vuonna 1976 annettu asetus korkealuokkaisen taimiaineiston tuottamisesta Maatalouden tutkimuskeskuksessa johti tervetaimiaseman perustamiseen Laukaaseen seuraavana vuonna. Terveen taimimateriaalin tuottaminen toteutetaan pääpiirtein siten, että Maatalouden tutkimuskeskuksen puutarhaosasto valitsee puhdistettavan materiaalin arvokkaiksi katsotuista lajikkeista, kasvitautiosasto ja tuhoeläinosasto puhdistavat materiaalista ydinkasvit lisättäviksi edelleen valiotaimiksi tervetaimiasemalla. Tervetaimiaseman tehtäviin kuuluu myös ydinkasviaineiston ylläpito terveenä.

Tervetaimiasema toimi pitkään varsin vaatimattomissa tiloissa, kunnes uudet asianmukaiset tutkimus- ja tuotantotilat valmistuivat talvella 1985. Vuodenvaihteessa 1988 tervetaimiasema muuttui liikelaitoksesta Maatalouden tutkimuskeskuksen erikoistutimusasemaksi. Tervetaimiaseman toiminta on kehittynyt voimakkaasti viime vuosina. Maatilahallituksen hyväksymille taimitarhoille on myyty pääasiallisesti mansikan, vadelman, herukoiden ja karviaisen valiotaimia. Nämä erikoistaimitarhat tuottavat valiotaimista ns. tarkastetut käyttötaimet sekä ammatti- että harrastelijaviljelijöille. Suomessa myydyistä mansikantaimista 90 %, vadelman taimista noin 50 % ja herukoiden taimista noin 25 % on tarkastettuja käyttötaimia.

Tervetaimituotantoa edelleen kehitettäessä ei enää niinkään panosteta tervetaimiasemalta myytävien taimien määrän lisäämiseen, vaan tuotantomenetelmien, tuotteiden ja tuotevalikoimien kehittämiseen. Pyrkimyksenä on lisääntyvän tutkimuksen avulla tuottaa enenevässä määrässä solukkolisättyä materiaalia, jota myydään taimistoille joko solukkoviljelminä tai pieninä taimina. Perinteisten kasvilajien lisäksi on pyrkimyksenä laajentaa tuotevalikoimaa siten, että myös erikoiskasveja tarvitseville voidaan tarjota aitoa ja tervettä lisäysaineistoa. Tuotantoon on alettu ottaa mukaan kasvilajeja myös viherrakentamisen tarpeisiin.

LOW LEVEL OF CONTAMINANTS IN FINNISH FOODS AND DIETS

JORMA KUMPULAINEN

KUMPULAINEN, J. 1988. **Low level of contaminants in Finnish foods and diets.** Ann. Agric. Fenn. 27: 219—229. (Agric. Res. Centre, Centr. Lab., SF-31600 Jokioinen, Finland.)

The present paper reviews the levels of heavy metals, pesticides, herbisides, organochlorine and polyaromatic compounds in Finnish foods and diets as compared with those from various Western European countries and the tolerance limits established by the FAO/WHO.

The levels of lead and cadmium were generally significantly lower in Finnish staple foods as compared with those from other countries, respectively. Furthermore, the low level of toxic heavy metals of Finnish foods was clearly reflected in the total dietary intake of the Finns: the average intakes of lead, cadmium and mercury were only approximately 5 %, 15 % and 5 % of the FAO/WHO Provisional Tolerable Weekly Intakes, respectively, being among the lowest average intakes reported in the literature. Levels of neutral organochlorine compounds in fat containing Finnish agricultural products were low compared to literature values. The level of PCB in Finnish beef and milk was particularly low compared to literature values from other Western European countries, respectively.

The average intake of neutral organochlorine compounds in Finland was 0.08 % (DDT), 0.3 % (HCH), 4.2 % (HCB) and 1.4 % (Heptachlor) of the ADI values as established by the FAO/WHO. Also, the level of 9 mutagenic or carcinogenic polyaromatic compounds was lower in Finnish wheat flour compared to that from a Central European country, respectively. In conclusion, the low levels of contaminants in Finnish foods were propably due to many contributing factors such as remote location, low population density, cold climate and relatively stringent legislation in terms of environmental contaminants, pesticides, and fertilizers.

Index words: Joods, diets, contaminants, heavy metals, organochlorine and polynuclear aromatic compounds, pesticides, herbicides.

INTRODUCTION

Agricultural products and processed foods may contain various types of natural and manmade toxicants. According to their origin, toxic compounds in foods may be divided into the following groups:

a) compounds of biological origin, such as glycoalcaloids in potatoes which are formed naturally, or toxins produced by microorganisms,

b) residues due to the use of agricultural chemicals, or hormonal or veterinary medicinal treatment of farm animals,

c) environmental contaminants, such as heavy metals, organochlorine compounds (OC) and polycyclic aromatic hydrocarbons (PAH) and,
d) toxic compounds, which are residues of, or synthesized during food processing, such as contaminants from food packaging materials or mutagenic compounds formed in the heat treatments of foods.

Certain groups of the compounds listed above, such as microbial toxins or residues of veterinary medicines, occur only rarely in foods while others such as environmental contaminants, due to their stable chemical structure and tendency to accumulate in the food chain are always present in foodstuffs. As the scope of the present paper does not permit the author to deal with the entire field of food toxicants, the present paper focuses chiefly on the occurrence of environmental contaminants in Finnish foods and diets as compared with those from other countries and on the concentration and intake tolerance limits as set by the FAO/WHO.

HEAVY METAL CONTENTS OF FINNISH AGRICULTURAL PRODUCTS AND DIETS

The Central Laboratory of Agricultural Research Centre has served as the Liaison and Analytical Centre for the Trace Elements in Food Sub-network of the FAO European Cooperative Network on Trace Elements established in 1983 (ANON. 1983). In this connection, nationally representative staple food and total diet samples from various European countries were determined by the Central Laboratory for 10 mineral elements including the heavy metals lead and cadmium. Well established and modern analytical techniques as well as suitable certified reference materials were employed to guarantee the analytical quality of our results (KUMPULAINEN and PAAKKI 1987).

The results obtained for nationally representative pooled samples of whole wheat, wheat flour, potato, pork and milk from Austria, the Federal Republic of Germany, Scotland, Sweden and Finland have been published by the FAO (KUMPULAINEN 1986). In the above FAO report the participating countries were coded, Finland's code being 5. The results show that the trace element quality of Finnish agricultural products is high: the concentration levels of the essential trace elements Fe, Zn, Mn and Cu in Finnish wheat and wheat flour were higher than those of the other participating countries, while the levels of toxic heavy metals lead and cadmium were lower or similar to those of comparable products from other European countries. The level of cadmium concentration was significantly lower in Finnish potatoes than that in potatoes from other participating countries. The level of lead content was much lower in Finnish wheat, wheat flour, milk and potatoes as compared to similar products from other participating European countries.

Unpublished results obtained for concentrations of 10 mineral elements in nationally representative samples from the three successive crops of various European countries during 1984—1986 are available. In this paper the results obtained for lead and cadmium will be presented in part. Thus far, 10 countries have provided samples for the study. In terms of the toxic elements lead and cadmium, the results obtained confirm those found in the 1984 samples: the level of lead concentration determined in nationally representative Finnish milk samples was only half of that present in samples from most Central European countries (Table 1). Similarly, the level of lead content in Finnish wheat flour (Table 2), whole wheat

(Table 3), potatoes (Table 4) and pork (Table 5) is significantly lower than that in comparable samples from other participating European countries. The level of cadmium concentration was very low (<5 μg/kg dry wt) in the meat and milk samples of all participating countries, and there were no clear differences in the concentrations of cadmium in wheat and wheat flour among samples from various countries. However, the level of cadmium content in Finnish potatoes was significantly lower compared to that of any other participating country (Table 6).

Low levels of lead and cadmium were also reported by SALMI and HIRN (1984) in Finnish meats intended for export thus confirming our results presented above. It is noteworthy that the levels of lead and cadmium content are

Table 1. Average lead content in nationally representative samples of pooled milk collected from Finland, France, Scotland, Sweden and the Federal Republic of Germany during 1984—1987.

Country code	Lead content (μg/kg dry wt.) Mean ± S.D.	No of analyses	a) Code of statistical difference
Finland	21 ± 1	44	A
2	19 ± 1	55	A
3	36 ± 1	3	C
4	40 ± 6	16	C
9	33 ± 5	7	B

a) Mean values without common characters are different ($P < 0.05$).

Table 2. Average lead content in nationally representative pooled samples of wheat flour collected from Austria, Finland, Sweden, Switzerland and the Federal Republic of Germany during 1984—1986.

Country code	Lead content (μg/kg dry wt.) Mean ± S.D.	No of analyses	a) Code of statistical difference
Finland	11 ± 1	48	B
2	8 ± 1	48	A
3	54 ± 15	12	D
1	24 ± 8	12	C
6	8 ± 2	8	A B

a) Mean values without common characters are different ($P < 0.05$).

Table 3. Average lead content in nationally representative pooled samples of whole wheat from Austria, Finland, Scotland, Sweden, Switzerland, Turkey and the Federal Republic of Germany collected during 1984—1986.

Country code	Lead content (μg/kg dry wt.) Mean ± S.D.	No of analyses	a) Code of statistical difference
Finland	23 ± 2	48	A
1	32 ± 2	12	B
2	22 ± 3	48	A
3	35 ± 2	8	B
4	32 ± 4	8	B
6	24 ± 2	8	A
8	31 ± 6	16	B

a) Mean values without common characters are different ($P < 0.05$).

Table 4. Average lead content in nationally representative pooled samples of potatoes collected from Finland, Norway, Scotland and Sweden during 1984—1986.

Country code	Lead content (μg/kg dry wt.) Mean ± S.D.	No of analyses	a) Code of statistical difference
Finland	11 ± 2	30	A
2	15 ± 2	48	A
4	23 ± 2	16	B
7	23 ± 3	12	B

a) Mean values without common characters are different ($P < 0.05$).

Table 5. Average lead content in nationally representative pooled samples of pork collected from Finland, a Central European and a Scandinavian country during 1984—1987.

Country code	Lead content (μg/kg dry wt.) Mean ± S.D.	No of analyses	a) Code of statistical difference
Finland	13 ± 3	48	A
Scandinavian country	17 ± 6	24	A
Central European country	47 ± 2	4	B

a) Mean values without common characters are different ($P < 0.05$).

Table 6. Average cadmium content in nationally representative pooled samples of potatoes collected from Finland, Norway, Scotland, and Sweden during 1984—1986.

Country code	Lead content (μg/kg dry wt.) Mean ± S.D.	No of analyses	a) Code of statistical difference
Finland	48 ± 10	44	A
2	83 ± 7	48	B
4	105 ± 4	16	C
7	76 ± 5	16	B

a) Mean values without common characters are different ($P < 0.05$).

remarkably constant throughout the three successive crops within the same country. Although none of the samples analysed was excessively high, with regard to the present tolerance limits for toxic heavy metals as set by the FAO/WHO (ANON. 1978b and 1978c) or by European governments, it is clear that the level of toxic heavy metals should be kept as low as possible in staple foods that constitute the raw materials for processed foods and are consumed in great quantities.

Low levels of toxic heavy metals in Finnish staple foods are clearly reflected in the levels of these elements in Finnish diets. As a contribution to the previously described FAO research program, a market basket diet representing the average food consumption of the Finns was composed from 920 kgs of collected foodstuffs representing 185 various food commodities. The foodstuffs were divided into nine food groups and homogenized by Ti-blades then freeze dried. The total diet and the food group homogenates were determined along with other trace elements for lead, cadmium and mercury.

However, as the effect of food preparation was not fully represented in the above indicated Finnish market basket diet, another type of total diet had to be included for the evaluation of the dietary intake of heavy metals in Finland. For that purpose, homogenized weekly diets from 11 university hospitals throughout Finland were collected and determined for lead, cadmium and mercury.

Table 7 summarizes the results obtained for lead, cadmium and mercury in the determinations of nationally representative market basket and 7—d hospital diets as well as a pooled diet composed of 77 individual 24—h diets of Finnish men. Analyses of these diets resulted in unanimously low figures for the average lead, cadmium and mercury intakes in Finland (KUMPULAINEN et al. 1978a, b, SINISALO et al. 1987).

Recently, the FAO/WHO Global Environmental Monitoring Programme (GEMS) has published a report on the average lead and cadmium intake from foods of various countries and compared these intakes with the Provisional Tolerable Weekly Intakes (PTWI) as established by the FAO/WHO (ANON. 1978b, c). Fig. 1 shows the average intake of lead in Finland as compared to that of other countries, and to the PTWIs. It indicates that the average lead intake in Finland is the lowest compared with any country that provided its results to GEMS. Similarly, Fig. 2 demonstrates that the average cadmium intake from Finnish foods is one of the lowest compared with the data from GEMS (ANON. 1987).

Table 7. Average dietary intakes of lead, cadmium and mercury in Finland estimated on the basis of analyses of nationally representative market basket and duplicate diets.

Type of diet	Lead		Cadmium		Mercury	
	Intake (μg/MJ)	Intake/PTWI* (%)	Intake μg/MJ)	Intake/PTWI* (%)	Intake (μg/MJ)	Intake PTWI* (%)
Market basket diet	1.8(1	4.2	1.0(1	14.0	0.193	5.3
7-day hospital diets	2.0(2	4.7	0.96(2	13.4	0.224	5.9
Pooled diet made from 77 24-h diets of Finnish men	3.3(3	7.7	1.19(3	17.0	—	—

*)PTW1 = FAO/WHO Provisional Tolerable Weekly Intake (See ref. ANON. 1978b)

1) KUMPULAINEN et al. 1987a
2) SINISALO et al. 1987
3) KUMPULAINEN et al. 1987b

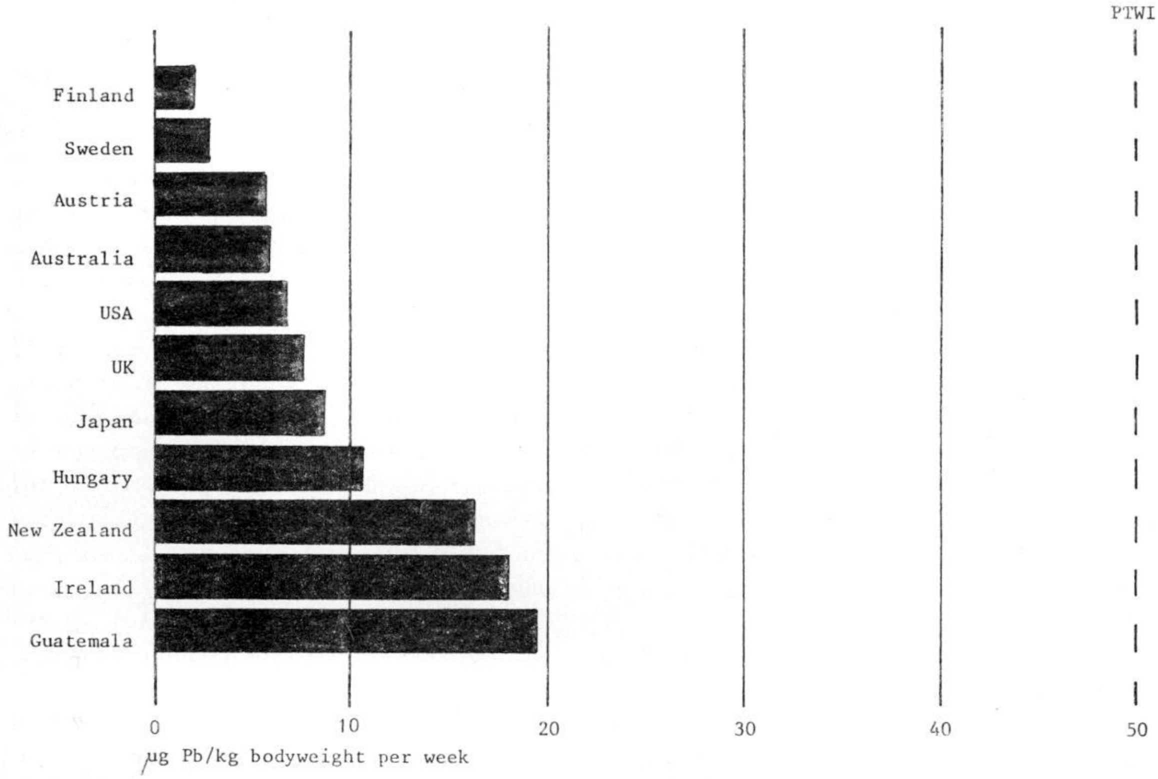

Fig. 1. Dietary intake of lead in various countries as reported by the GEMS/FOOD (ANON. 1987). For original Finnish data see Enclosures 1 and 2.

Bars represent median values. PTWI = Provisional Tolerable Weekly Intake as set by the FAO/WHO (ANON. 1978b and c)

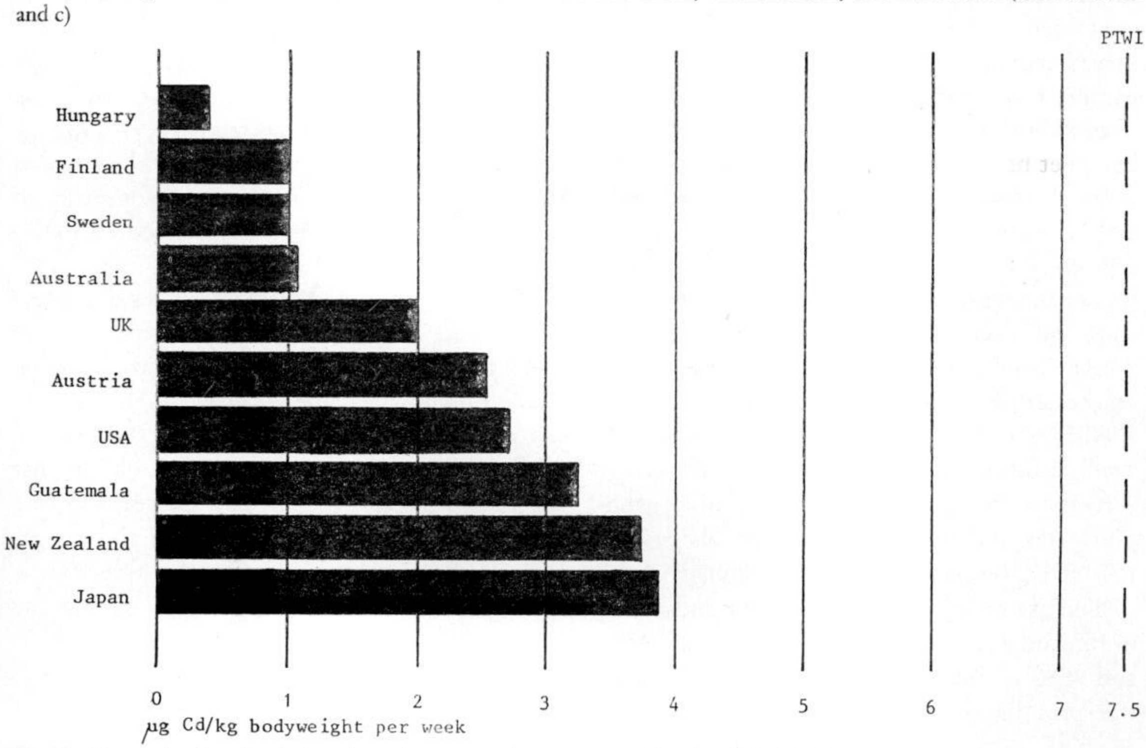

Fig. 2. Dietary intake of cadmium in various countries as reported by the GEMS/FOOD (ANON. 1987). For original Finnish data see Enclosures 1 and 2.

Bars represent median values. PTWI = Provisional Tolerable Weekly Intake as set by FAO/WHO (ANON. 1978b and c)

CONTENTS OF RESIDUES OF PESTICIDES, HERBICIDES AND ORGANOCHLORINE COMPOUNDS IN FINNISH FOODS

Sales of pesticides in Finland in 1986 totalled 1951 tons of active ingredients (HYNNINEN and BLOMQVIST 1987). Herbicides represented 1532 tons followed by insecticides (140 tons) fungicides (111 tons), growth regulators (81 tons), forest pesticides (69 tons), insect repellents (10 tons) and other insecticides (7.5 tons) (HYNNINEN and BLOMQVIST 1987).

The annual use of pesticides has remained rather constant over the past 5 years and the level of consumption is lower than that in most other countries (TIITTANEN 1983). Moreover, the compounds presently accepted for use are easily degradable in nature and more specific than those used in the past. Therefore the levels of pesticide and herbicide residues are very low in Finnish staple foods. Recently, we determined the residues of 11 pesticides and 6 herbicides currently in use in samples of wheat that represented total Finnish wheat production during 1984—1985. Only one sample contained 0.05 mg/kg vinclozolin, while the others did not contain residues of any of the compounds in detectable concentrations.

Pesticide residues present in vegetables and berries are somewhat higher than those in cereals. However, the residue levels of benomyl, dithiocarbamates, organophosphorus compounds and post harvest chemicals are much higher in imported fruits and vegetables than those in domestic products (ANON. 1982). These compounds represent over 80 % of intakes of pesticide residues altogether (ANON. 1982). Even then, in 1977—1980 the estimated average intake of dithiocarbamates altogether was approximately 8 % and that of organophospates and post harvest chemicals 3 % of the ADI's, respectively (ANON. 1982).

The use of organochlorine compounds (OC) in Finland radically decreased during the 1970's and 1980's. The use of DDT as an insecticide was prohibited in Finland in the early 1970's, and the use of polychlorinated biphenyls (PCBs) is practically nonexistent. Lindane (99 % gamma hexachlorocyclohexane) is used in Finland as an insecticide for rape and turnip rape. However at 1.9 tons/year, the annual consumption of lindane is lower than that of most European countries. Chlordanes are not registered as insecticides for agricultural use in Finland although heptachlor, a component of technical chlordane mixtures, is used by the plywood industry to protect plywood intended for export to tropical countries. Therefore as only a scant amount of heptachlor is released into the Finnish natural environment, it cannot be regarded as a pesticide commonly used in Finnish agriculture.

Although most OCs are now banned in Finland due to their lipophilic nature and slow decompostion rate, residues of these compounds can still be found in food fats. MOILANEN et al. (1982) have determined the time trends of levels of neutral OCs in fish from the Baltic Sea. Their results showed that the levels of PCB and DDT have decreased considerably in fish tissues from 1979—1982.

The Ministry of Agriculture and Forestry has financed research at the Central Laboratory of Agricultural Research Centre aimed at determining the contents of OCs in Finnish agricultural products and diets. Residues of neutral OCs were investigated in Finnish rape and turnip rape seeds, margarine, butter, and vegetable oils by the same authors (MOILANEN et al. 1986a). The results showed that the levels of OCs, although low already in 1978, had further decreased in rape and turnip rape seeds during 1978—1984. With regard to butter and margarines, the levels of OCs were very low compared to the residue limits as set by the FAO/WHO (ANON. 1978a, 1979) (Table 8).

As a contribution to the FAO/WHO organochlorine monitoring program, nationally

Table 8. Average consumption of butter and margarines, their concentrations of organochlorine compounds and their estimated intakes in Finland as compared with the residue limits and ADI. (From MOILANEN et al. 1986a).

	Butter	Margarines	Residue limits (μg/kg) FAO/WHO	Residue limits (μg/kg) USA	Total	per kg body wt.	FAO/WHO ADI (μg/kg)	Intake/ADI (%)
Consumption								
— total (g/d)	30.1	19.5						
— fat (g/d)	26.5	16.9						
concentrations (μg/kg)								
Σ PCB	64.3	55.1	—	2500				
Σ DDT	1.0	0.0	1250	—				
HCH	15.0	5.7	—	300				
HCB	9.7	0.8	500	—				
Heptachlor	5.2	5.0	10	—				
Intakes (μg/d/70 kg)								
Σ PCB	1.94	1.07	0.013		3.023	0.043		
Σ DDT	0.03	0.00	0.003		0.033	0.001	5.0	0.002
HCH	0.45	0.11	0.081		0.641	0.009	10.0	0.090
HCB	0.29	0.02	0.002		0.308	0.004	0.6	0.600
Heptachlor	0.16	0.10	0.048		0.306	0.004	0.5	0.800

Table 9. Mean levels of organochlorine compounds in milk and beef fat in different countries (μg/kg fat) (From MOILANEN et al. 1986b).

Country	Year	PCB	DDT	HCB	HCH	Heptachl.
Milk						
France	70—80	200	11	24	91	17
Germany	77—78		20—26	14—24		2—5
Netherlands	76—79	200	20—26	20—40	40—70	20—50
Japan	76—79	30				
Brazil	79		220		220	
Switzerland	71—79			1—45	30—90	
Italy	79—80		59		40	96
India	78—81		5600			
Finland	84	13	4	13	10	2
Beef fat						
Netherlands	77	240				
Switzerland	74—76	28—71			40	20
Austria	78	110—160				
Italy	75		120		30	11
Czechoslovakia	81		0—495	5—5500	5—56	
Denmark	74—76	110	140	30		
Sweden	72—77		50	110	170	
Finland	84	39	3	2	8	4

representative samples of milk, eggs, beef, pork chops, game, animal livers as well as fish-liver oils were analysed for contents of neutral OCs. From these concentration data and the average food consumption figures obtained from the Finnish food balance sheets, the average intakes of OCs from the Finnish diet were estimated (MOILANEN et al. 1986b).

The mean levels of OCs in nationally representative samples of milk and beef fat were very low when compared with those reported from other countries (Table 9). The levels of

PCB were particularly low in Finnish milk and beef samples compared with those from Central European countries.

Table 10 summarizes the results obtained in the determination of OC concentrations in representative samples of common foodstuffs containing fat as well as the estimated average intakes of these compounds in Finland (MOILANEN et al. 1986b). The average intakes of DDT, hexachlorocyclohexane, heptachlor, and hexachlorobenzene were 0.08, 0.3, 1.4 and 4.2 % of the acceptable daily intakes (ADI) as set by the FAO/WHO, respectively.

Table 10. Average consumption of fat-containing foodstuffs (g/day 1983), their concentrations of organochlorine compounds and their estimated intakes (μg/day) in Finland. (From MOILANEN et al. 1986b).

	Consumption		Concentrations μg/kg						Intakes μg/day					
	Total g/day	Fat g/day	ΣPCB	ΣDDT	HCH	HCB	Hpchl.	Tox.	ΣPCB	ΣDDT	HCH	HCB	Hpchl.	Tox.
Fishes	52.6	2.2												
Baltic herring[a]	20		200	100	30	30	—	—	4.0	2.0	0.6	0.6	—	—
Other fishes[a]	30		50	10	—	—	—	—	1.5	0.3	—	—	—	—
Dairy products	530.2	27.9	14.0	3.8	11.3	13.5	2.0	7.0	0.39	0.11	0.32	0.38	0.06	0.20
Whole milk	482.8	18.8							0.26	0.07	0.21	0.25	0.04	0.13
Cream	16.4	3.1							0.04	0.01	0.04	0.04	0.01	0.02
Milk powder	8.8	0.7							0.01	0.003	0.01	0.01	0.01	0.01
Cheese	22.2	5.3							0.07	0.02	0.06	0.07	0.01	0.04
Fats and oils														
Butter[a]	30.1	26.5	64.3	1.0	15.1	9.7	5.2	—	1.94	0.03	0.45	0.29	0.16	—
Margarines[a]	19.5	16.9	55.1	—	5.7	0.8	5.0	—	1.07	—	0.11	0.02	0.10	—
Vegetable oils[a]	16.1	16.1	0.8	0.2	2.0	—	1.0	—	0.01	0.003	0.003	—	0.02	—
Hens eggs[a]	28.0	3.1	102.3	13.0	13.9	1.2	—	—	2.86	0.36	0.39	0.03	—	—
Meat products														
Beef	55.8	4.3	39.5	2.3	8.0	2.2	3.7	4.3	0.17	0.01	0.03	0.01	0.02	0.02
Pork	84.9	20.4	100.0	2.0	18.0	18.0	6.0	6.0	2.04	0.04	0.37	0.37	0.12	0.12
Inner organs	21.5	1.7	224.4	1.0	23.4	25.7	5.2	15.1	0.38	0.002	0.04	0.04	0.01	0.03
					Total:				14.35	2.86	2.31	1.74	0.49	
					Per kg body weight (70 kg)				0.205	0.041	0.033	0.025	0.007	0.005
					FAO/WHO: ADI μg/kg/day				—	50	10	0.6	0.5	—
					Intake/ADI (%)				—	0.08	0.3	4.2	1.4	—

a Concentrations/whole product

POLYCYCLIC AROMATIC HYDROCARBONS IN FINNISH AGRICULTURAL PRODUCTS

PAHs are formed in the combustion of organic compounds at relatively low temperatures, i.e. at conditions which develop smoke. Thus, industry and traffic are the most important sources of these compounds, many of which are known to be mutagenic and some carcinogenic. LARSSON (1986) has recently determined the intake of 9 PAHs known to be carcinogenic or mutagenic from Swedish foods. His study revealed that cereals are by far the most important source of these compounds followed by food fats, smoked meat and leafy vegetables.

We therefore decided to determine the contents of those 9 PAHs known to be carcinogenic or mutagenic in pooled samples of wheat flour representing the wheat flour consumption of the entire populations of Finland, a Central European and a Scandinavian country. The results showed that the mean concentration of these compounds in the Finnish flour was approximately 40 % of that found in the flour of one of the countries in the comparison (Table 11). It seems logical to conclude that the difference was probably due to the lower exposure of Finnish wheat to industrial and traffic smoke as compared to that of a more heavily industrialized Central European country with a higher concentration of motor vehicles and heavy industry.

Table 11. Mean concentration of 9 PAHs known to be mutagenic or carcinogenic in nationally representative samples of wheat flour from Finland, a Central European and a Scandinavian country (TUOMINEN et al., unpublished results).

Sampling year	Scandinavian country (n = 8)	Finland (n= 8)	Central European country (n = 4)
		μg/kg d.wt. ± S.D.	
1984	1.3 ± 0.2	5.0 ± 2.4	12.0
1985	4.4 ± 2.6	2.4 ± 1.3	6.1
Mean ± S.E.M.	2.9 ± 1.6	3.7 ± 1.3	9.0 ± 3

CONCLUSIONS

Clearly, the results reviewed in the present paper demonstrate that the level of the chief industrial contaminants and persistent pesticide residues are remarkably low in Finnish agricultural products and foods in comparison with other industrialized Western countries or tolerance limits as set by the FAO/WHO. This is due to a number of factors. Probably most important is stringent agricultural legislation in Finland which restricts the use of pesticide residues, sewage sludge or high cadmium-phosphate fertilizers in agriculture. Similarly, exposure of the Finnish natural environment to industrial and traffic pollutants is strictly regulated by pollution control laws. Finally, our low population density and advantageous geographic location (low level of long-range transport of pollutants) and cold climate (reduces the need for pesticides) contribute to the fact that Finnish foods and agricultural products are low in contaminants and of excellent hygienic quality.

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Manuscript received March 1988

Jorma Kumpulainen
Agricultural Research Centre
The Central Laboratory
SF-31600 Jokioinen, Finland

SELOSTUS

Alhainen kontaminanttipitoisuustaso suomalaisissa elintarvikkeissa ja ravinnossa

JORMA KUMPULAINEN

Maatalouden tutkimuskeskus

Tässä kirjallisuuskatsauksessa on selvitetty suomalaisten peruselintarvikkeiden ja dieettien raskasmetalli-, pestisidi-, herbisidi-, organokloori- ja polyaromaattisten yhdisteiden pitoisuuksia sekä verrattu niitä muiden, pääasiassa länsieurooppalaisten maiden vastaavien tuotteiden pitoisuuksiin sekä kansainvälisiin toleranssirajoihin soveltuvin osin. FAO:n eurooppalaisen hivenainetutkimusprojektin puitteissa Maatalouden tutkimuskeskuksen keskuslaboratoriossa on määritetty kansallista tuotantoa edustavien Itävallasta, Norjasta, Länsi-Saksasta, Ranskasta, Skotlannista, Sveitsistä, Ruotsista, Turkista ja Suomesta v. 1984—1986 kerättyjen vehnä-, vehnäjauho-, maito-, sianliha- ja perunanäytteiden 10 kivennäisaineen pitoisuudet mukaanlukien haitalliset raskasmetallit lyijy ja kadmium.

Tulokset osoittivat, että suomalaisten peruselintarvikkeiden ravitsemuksellisesti välttämättömien kivennäisaineiden pitoisuudet olivat korkeampia (vehnä) tai vastaavia kuin ulkomaisten tuotteiden, sen sijaan lyijyn ja kadmiumin pitoisuudet olivat yleensä pienempiä tai saman suuruisia kuin vastaavien ulkomaisten tuotteiden pitoisuudet. Myös suomalaisten keskimääräistä kulutusta edustavan ja tiettyjä väestöryhmiä edustavien kokonaisdieettien lyijy-, kadmium- ja elohopeapitoisuudet olivat yhtäpitävästi ainoastaan noin 5 %, noin 15 % ja noin 5 % FAO/WHO:n korkeimmista sallituista viikkosaantirajoista vastaavasti ja huomattavasti pienempiä kuin useimmissa muissa maissa.

FAO/WHO:n organoklooriyhdisteiden seurantaohjelmaa varten Maatalouden tutkimuskeskuksen keskuslabo-

ratorio on yhteistyössä Valtion teknillisen tutkimuskeskuksen (VTT) elintarvikelaboratorion kanssa määrittänyt edustavista näytteistä maidon ja maitotuotteiden, elintarvikerasvojen, kananmunien, lihan ja lihatuotteiden sekä elinten ja riistan organoklooriyhdistepitoisuudet. Näiden tulosten ja VTT:n elintarvikelaboratoriossa aiemmin määritettyjen kalan ja kalatuotteiden organoklooripitoisuustulosten avulla on voitu arvioida suomalaisten elintarvikkeista keskimäärin saamien organoklooriyhdisteiden määrät. Keskimääräinen saanti oli noin 0.08 % (Σ DDT), 0.3 % (HCH), 4.2 % (HCB) ja 1.4 % (Heptachlor) FAO/WHO:n ADI-arvoista.

Verrattaessa suomalaisen naudan- ja maitorasvan organoklooriyhdisteiden pitoisuuksia kirjallisuudessa esiintyviin vastaavien ulkomaisten tuotteiden pitoisuuksiin voidaan todeta suomalaisten tuotteiden olevan yleensä selvästi puhtaampia. Erityisesti PCB:n suhteen suomalaiset eläinrasvat näyttävät olevan huomattavasti puhtaampia kuin keskieurooppalaiset vastaavat tuotteet. Käytössä olevien herbisidien ja pestisidien osalta jäämiä esiintyy kotimaisissa peruselintarvikkeissa erittäin vähäisiä määriä ja suurin osa näistä yhdisteistä saadaankin tuontihedelmistä ja vihanneksista.

Verrattaessa yhdeksän muta- tai karsinogeeniksi todetun polyaromaattisen yhdisteen pitoisuuksia vehnäjauhonäytteissä todettiin suomalaisen ja vertailussa mukana olleen skandinavian maan näytteiden keskimääräiset pitoisuudet selvästi alemmiksi kuin erään keskieurooppalaisen maan vastaavien näytteiden pitoisuudet.

Yhteenvetona voidaan todeta, että yllä esitettyjen kontaminanttien pitoisuudet ovat keskimäärin selvästi pienempiä suomalaisissa elintarvikkeissa verrattuna vastaaviin keskieurooppalaisiin tai useimpiin muiden pitkälle teollistuneiden maiden tuotteisiin. Johtopäätös on, että Suomen syrjäinen sijainti, pieni väestötiheys, kylmä ilmasto ja suhteellisen tiukka vierasaine-, ympäristö-, pestisidi- ja lannoitelainsäädäntö sekä hyvä maatalouskäytäntö selittävät pääosin suomalaisten elintarvikkeiden alhaisen kontaminanttipitoisuustason.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 231—246 (1988)

Seria ANIMALIA DOMESTICA N. 85 — Sarja KOTIELÄIMET n:o 85

USE OF THE INDIVIDUAL ANIMAL MODEL IN THE GENETIC EVALUATION OF BREEDING ANIMALS

ASKO MÄKI-TANILA and JARMO JUGA

MÄKI-TANILA, A. & JUGA, J. 1988. **Use of the individual animal model in the genetic evaluation of breeding animals.** Ann. Agric. Fenn. 27: 231—246. (Agric. Res. Centre, Dept. Anim. Breed., SF-31600 Jokioinen, Finland.)

Animal production research is currently investigating and developing methods that have been made available by new technology. These new methods will lead to higher productivity which will be reflected in lower consumer prices as well as the improved competitiveness of the production sector. Many of the improvements in animal breeding strategies involve only marginal increases in cost but will provide large economic returns which makes their implementation easy. A major exercise in animal breeding research is the development of genetic evaluation procedures. The main problem in predicting an animal's genetic merit is the elimination of effects due to environment and genetic trend. Advances in computing hardware and software have enabled the implementation of genetic evaluation methods for all animals in the production system by means of an individual animal model. This method will eliminate even small biases due to dam selection. When all animals are evaluated under the same uniform system the number of candidates for selection will substantially increase. Some examples are cow evaluation in breeding programs utilizing artificial insemination and embryo transfer and the evaluation of sows and boars for reproductive traits. The individual animal model can be generalized beyond conventional breeding value prediction to include special genetic effects and even for the testing of the overall effects of an inserted foreign gene.

Index words: animal model, estimation of breeding values.

Technological advances have been and continue to be important to the development of Finnish animal industries leading to improvements in productivity. Agricultural policy has provided the incentives for farmers to adopt and apply new technology. This has been achieved by the provision of financial support, marketing arrangements and policies to modernize farms and animal production. At the farm level the prices received in relation to the cost of inputs have generally provided incentives for adoption of new techniques. Technical progress has thus facilitated the transfer of labour from agriculture into other sectors to the benefit of the overall economy.

As is the case with all industries, animal production is subject to the laws of supply and demand — by 10—35 % — but also the commodities now exceeds not only domestic demand — by 25—45 % — but also the markets for export. Higher productivity will result in improvements in efficiency that are beneficial to consumers and taxpayers, and it will also improve the competitiveness of individual farmers. This will be reflected in lower unit costs of production and consumer prices, and in the ability of the producer to meet modern market requirements in terms of quantities, quality and continuity of supply. All of this suggests that in spite of the problems of over-supply, changing methods and technologies will be important to sustaining and developing the future of the animal production industry in Finland. Increased productivity will reduce demand for the resources of land, labour and capital used in food production for any given size of market. From an individual farmer's point of view, the new technology will improve his competitiveness, maintain or increase his market share, protect his income and allow him to meet market requirements. Many of the improvements involve only marginal increases in cost, or would provide input savings. Moreover any new investments would be minimal and would be rapidly absorbed.

Animal production research and development should concentrate on factors which will improve overall economic efficiency. In Finland, we are fortunate in that the breeding animals of both major species, dairy cattle and pigs, have been selected on the basis of their economic merit for many years. When we contemplate the future, the type and quantity of input in animal production is unlikely to undergo changes which would invalidate the current definition of efficiency. In other words, the main criteria by which breeding animals are ranked today will apply also for the decade or two ahead (c.f. MAIJALA 1976). It would be very unwise and short-sighted to reconstruct genetic improvement programs according to temporary overproduction tendencies, as we are almost certainly heading towards more open competition nationally and internationally.

Much of the contribution of animal breeding research has been to encourage breeders to make rational decisions in selection programs such as to set up recording systems for important traits and pay less attention to traits other than production. Geneticists have also shown how to best design breeding programs and how information should be put together. For example, how much weight should be attached to a boar's own versus his full-sibs' records and what kind of economic value should be assigned to various production traits. There is still great scope for increases in the rates of genetic gain as many of the ideas, some of which might be quite foreign to the practical judgement of a breeder, are still to be adopted. Scientists should provide information to enable a breeder to make practical decisions; if a breeder intends to be competitive he will utilize this information.

Within the last few years, the quality and quantity of practical applications in the prediction of an animal's genetic merit or breeding value have changed considerably. The first and most important requirement for a successful breeding program is to enable animals to be treated equally and compared under conditions as similar as possible. As many breeding programs use the production records expressed at the farm level, the principle mentioned above can be fulfilled only conceptually, i.e. statistical methods are needed to account for environmental differences. As a tool to achieve this, Best Linear Unbiassed Prediction has become a worldwide norm, the method is better known by its acronym, BLUP. The recent and forthcoming applications of this procedure will be discussed in this paper. The main emphasis will be on the so-called individual animal model, with regard to the possibilities and advantages it offers.

An objective of any improvement program must be to optimize the use of the data collected in the application of selection decisions. The BLUP methodology has been developed around the evaluation of dairy bulls and cows through attempts to combine the power of least squares analysis to estimate the herd effects, with the features of selection index to predict animals' genetic merits using various types of relative information. The problem can be visualized as solving the animal's breeding value (a) from the equation

production record = management effects + breeding value + residual

when the overall genetic variation (σ_a^2) or its proportion to the total variation (heritability, h^2) in the population is assumed to be known. The symbols, production record is denoted by y, management effects by b, and the rest which we do not consider as specified, by e, we thus have the record from an animal j in the management environment i

$$y_{ij} = b_i + a_{ij} + e_{ij}$$

A brief method to write these equations for hundreds, and more realistically, for thousands of animals from several herds, is the use of matrix and vector expression.

In order to predict breeding values with this kind of model we aim at a function of the observations which is linear. A condition for prediction is that it has the smallest standard error amongst those making allowance for environmental differences; in other words we simultaneously eliminate nuisance factors while the 'best' predictions are computed. HENDERSON (1963) showed that this is accomplished by solving a set of equations comprised of two types. For each environment i we have

$$n_i b_i + \sum_j a_{ij} = \sum_j y_{ij}$$

where n_i is the number of animals forming a record in the ith herd. By subscripting s for sire, d for dam, m for mate and p for progeny, we have according to the condition set above, for the breeding value of the ijth animal

$$(1)\quad b_i + (1 + 2k_a + .5k_a n_p)a_{ij} - k_a(a_s + a_d) + \sum_{\text{progeny}} (.5a_m - a_p)k_a = y_{ij}$$

where n_p is the number of progeny and $k_a = (1 - h^2)/h^2$.

In statistical terms we have treated environmental factors as fixed effects and genetic effects as random effects. The statistical phrasing for a set of equations involving both the estimation of fixed and the prediction of random effects are, appropriately or not, mixed model equations. Had we followed the vector — matrix presentation we would have obtained a compact and very general formulation, but for reasons of convenience a more explicit way to write out the equations was chosen.

Mixed model methodology provides us with very powerful techniques. Until quite recently, it was assumed that b is known, and the observations corrected for it could be handled by the selection index method. What BLUP of a actually represents, is nothing more than a selection index where the 'known' b is replaced by the least squares estimate which takes into account the heterogenous variation due to genetic relationship (HENDERSON et al. 1959, HENDERSON 1963). The selection index is always written in terms of heritability whereas as a corresponding mixed model parameter the ratio of the residual variance to the genetic one has become conventional: probably even to the extent that the generality and usefulness of the heritability concept has been missed.

Another difference in comparison to the selection index is the inclusion of information from relatives and mates. Progeny and parental predictions link the animal's breeding value prediction to those of the rest of the population. There are two significant corollaries from these properties. First, we can compare animals over generations and calculate genetic trends over time. Second, the effect of any type of selection can be accommodated.

The example we have dealt with so far is a simple model, but on a very general method. In the model for b we could have written any number of fixed effects and covariates. Likewise, genetic effects of any type, as well as non-genetic effects, such as environmental effects common to animals reared together or those common to repeated records on the same animal can be represented as random effects. If we consider interaction effects important, they can be included. In predicting breeding values, we included the value of information from other animals. As a step further, we could utilize the information given from other correlated traits. Writing out equations for such a multi-trait analysis case is a formidable task and the need to resort to matrix presentation becomes unavoidable.

Due to Mendelian inheritance the individual animal model $y_i = a_i + e_i$ is equivalent to a sire-dam model

$$y_i = a_{is} + a_{id} + e_i^*$$

where the residual variance is $.5\sigma_a^2$ larger than that of the previous one. When dealing with a species where the number of progeny per dam is very large, the evaluation could be based on this model. Some examples of such species are poultry and fish. Although the record of the animal itself is not considered, the loss in accuracy compared with the reduction in the number of equations is negligible.

The sire and dam model takes mate selection into proper account. If we consider dam selection merely to reflect the previous sire selection, her contribution to the model can be replaced by half of her sire's genetic value with the increase of the residual variance by $.25\sigma_a^2$. This so-called maternal grandsire model is probably the most favoured one in dairy sire evaluation routines. When dam selection is neglected completely, we have a sire model. The sire model has been the pioneering model in evaluation routines, but its extensive use has obviously increased the need for more efficient models where selection and changes of average genetic level over generations are properly taken into account.

Above were stated the benefits of mixed model equations obtained from considering the relatives' and mates' records in predicting breeding values. The formula (1) was written for a case where both parents are known, in terms of the individual itself and his progeny. In order to account for a lack of pedigree information, a slight modification is required for the coefficients (e.g. HENDERSON 1975a, THOMPSON 1977a). On the whole, the individual is compared back to his parents and then forward to his progeny according to simple Mendelian rules by following allele paths. Hence the occurrences and consequences of selection and sampling (genetic drift) are recorded and fully accounted for, also the collision of allele paths — inbreeding — falls within the monitoring capabilities of the random effect equations. The most comprehensive model for the contemplation of these aspects is the animal model. When we move toward more approximating models, the contributions from various types of relationships change. We can argue that there are different factors affecting vertical versus lateral relationships. Some cases of the animal model separate these by including some kind of full-sib effect which presumably consists of non-additive genetic and common environmental effects. We shall consider models with non-additive, especially dominant effects in a later chapter. Meanwhile, we hope that the current models and algorithms do not constrain the quality of predictions between and within generations.

When the data spans several generations, the importance of correct pedigree information cannot be over emphasized. The prediction for an animal lacking a parentage record is regressed towards zero; unless there is some information on the birth date or the origin of the animal to attach it to a group of contemporaries with some fixed genetic level. It is obvious that a newcomer into a population requires more progeny in order to attain the same accuracy in prediction with the animals which are descendants from the previous generation. In fact, much attention has been paid to the effect of migration on the prediction of breeding values. In the prediction model the grouping of animals is one solution, but it cannot handle the imminent linkage disequilibrium which occurs with migration.

Although there is no major step in extending the single-trait prediction to a two-trait or in general, to a multi-trait prediction, the number of parameters required increases rapidly. The consequences from the sampling errors of estimated genetic and environmental (co)-variances will augment one another in simultaneous use. With a high number of traits we might find some inconsistencies in trait relationships (HILL and THOMPSON 1978). This lack of consistency comes from partial correlations and heritabilities oftraits lying outside their permissible bounds. Although this finding was made in the selection index context, the same caution is necessary when animals are evaluated simultaneously for several traits. We might introduce some constraints (e.g. bending by HAYES and HILL 1981) to bring the estimates into an acceptable range but we still cannot be sure that the estimates are of much value. On these grounds, the overall usefulness of multi-trait predictions beyond, say, three traits could be questioned. There are situations in which the cost of recording could be drastically reduced by relying on correlations between traits. For example, in pigs the costly measurements of food intake could be carried out only in a sample of animals, if the correlations with other traits are known.

COMPUTING STRATEGIES

Procedures for the genetic evaluation of dairy cattle have been improved during the past 30 years through discoveries of more efficient computing algorithms and advances in computing hardware that have enabled the implementation of more realistic models. Against all of the advantages of an animal model, the disadvantage compared with simpler models is that many more equations must be solved. Recent work on computing strategies has suggested that the application of an animal model to national data is feasible.

Reduced Animal Model

The most obvious strategy to reduce the computing task is to minimize the number of equations to be solved simultaneously. In species where the female reproductive rate is high, the number of animals required for producing replacements is relatively small. A typical example of such an animal is the pig. When evaluating pigs we are likely to have many animal equations lacking progeny information. QUAAS and POLLAK (1980) suggested a major reduction in the magnitude of fitting an animal model by a straightforward exploitation of the relationship coefficients between animals (c.f. eq. 1). We solve the breeding value of a non-parental individual and replace this into his parents' equation and into the fixed (or random) effect equations which correspond to the individual's record. It is only these classes of equations which transmit the non-parent's information to the overall set of mixed model equations.

A practical application of this reduced animal model for pig evaluation by HUDSON and KENNEDY (1985) required only 10—20 % of the equations needed by the full animal model. If any of the non-parental predictions are desired, they can be easily obtained. Usually only the most recent non-parents are of interest for current selection decisions.

Multiple trait analysis

A prediction including several traits simultaneously is the next logical step because then it can be truly said that all available information — all relatives and traits — are employed. In turn, the predictions are more accurate and less affected by selection. Computing cost is a major disadvantage with multitrait prediction. There are, however, some special cases which lower computing requirements. If we have two traits — generalizations for more than two should be obvious — measured in all animals and we can consider the same environmental factors being important in the two traits, by utilization of the correlation structure between the traits we can make the prediction with two single-trait analyses (THOMPSON 1977b). The procedure — canonical transformation — is most applicable also in variance component estimation (e.g. THOMPSON and JUGA 1988). The next most simple pattern occurs when again we have the same environmental effects considered and the measurements on animals are missing in a systematic way. For example, if for culling reasons, the second lactation record on a cow does not exist, and all subsequent measurements are missing. Computation can be reduced by triangular transformation (e.g. SMITH and GRASER 1986).

Solving equations

After the mixed model equations are set up, we then wish to solve them. A small number of equations can be solved directly and explicitly in the computer memory. There are many advantages in this. In such cases we can construct confidence intervals around predictions, conduct hypothesis tests for fixed effects and estimate the variance components. Historically, this was first made possible by half-storing the symmetric set of equation coefficients. Furthermore, by taking advantage of the fact that for an animal model most of the coefficients are zero, even larger sets of equations could be stored in a memory space. Examples of such storing techniques applied in prediction problems are hashing and linked list methods (MISZTAL and HAUSSMANN 1985, TIER and SMITH 1988).

Almost without exception, the equations for practical evaluation lend themselves to being solved by iteration techniques. Iteration for solving systems of linear equations involves updating solutions sequentially by assuming that all solutions are known other than the one being updated. Steady developments in computer hardware are making it possible to run an iteration in the computer memory. Such a program can be simple to understand and easy to maintain. Although new storing techniques are becoming available, it is of interest to discuss the computing strategies when an external medium (magnetic disk or tape) must be used for storing purposes.

As an example let us consider a typical sire evaluation problem with a small herd size. We assume that there are 350 000 observations on cows in 120 000 herd-years. On average, assume that each year contains 4 daughters from 3 different sires. Including pedigree information we have altogether 7000 sires being evaluated. The first alternative is to store all the non-zero coefficients of the mixed model equations outside memory. The herd-year equations would produce 120 000 plus 360 000 non-zero elements, and for the sire equations the number would be the 360 000 plus the number of sires augmented by the number of elements due to relationships, say, 20 000. This gives a total of 860 000 which the program must read once at each round of iteration.

A common practice used to reduce the number of equations has been to eliminate the herd-year equations by acknowledging their contributions in sire equations. Although the total number of equations is reduced from 127 000 to a mere 10 000, the number of non-zero coefficients is — as a very conservative esitmate — around 900 000. Because of the elimination procedure the coefficient of an updated solution is smaller with respect to other coefficients in the equation, which consequently slows down the rate in obtaining a satisfactory solution. Furthermore, the elimination of equations involves several separate steps with consequent difficulties in understanding, maintaining and modifying the program.

SCHAEFFER and KENNEDY (1986) proposed a method which does not require formation of the coefficients explicitly. However, for each factor in the model, a file of the data must be read for each round of iteration. For our example this so-called indirect approach requires reading all the 350 000 records from the data file and 20 000 from a coded pedigree file. The procedure avoids the cumbersome intermediate steps caused by the elimination of herd-years with two main consequences. Firstly, the solutions converge much faster as the number of coefficients is drastically smaller. Secondly, we have solutions also for herd-year effects which provide very important information on management aspects for farmers.

APPLICATIONS

In this chapter we would like to briefly review the BLUP evaluation procedures which have been developed in Finland giving, however, the most emphasis to the methods and research around the use of individual animal model.

Sire evaluation in dairy cattle is performed by a maternal grandsire model (SYVÄJÄRVI et al. 1983). As a good proportion of herds have more than one breed, a better use of the data considering the small average size of the herds is obtained by fitting the breed as a fixed effect and evaluating all breeds together. Simulation work to study the effect of number of cows over a range of herd and year classification suggested that if records are preadjusted for season, a satisfactory grouping is accomplished by considering herd-year as a grouping criterion (OJALA et al. 1985). BLUP evaluation was implemented in 1981. The sire model is also used in evaluating trotters for their racing performance (OJALA et al. 1987).

Dairy Cow Evaluation

In Finland, the cow index of 4 % FCM yield is calculated annually for each recorded cow with at least one complete lactation record taking into account all previous lactations (SYVÄJÄRVI 1985). The records are corrected for age, lactation number, month of calving, and calving interval. The index procedure is a modification of the Direct Updating Method (CHRISTENSEN 1981). A cow's index is constructed from pedigree and production index in the conventional way by appropriate weighting. The BLUP of cows' breeding value employed an animal model with repeated records, additive genetic relationships and all information about sires and grandsires (HENDERSON 1975b).

The product moment and rank correlation between the different predictions were after pooling over herds .88 and .86, respectively (for more details, see JUGA 1985). A much smaller correlation might have been expected but we must bear in mind that the selection index method here utilizes sire-BLUP as well. A further improvement could be gained by a simultaneous sire-cow evaluation which would incorporate across-herd relationships and include a sire's evaluation directly rather than through an approximative method.

Cow's predicted breeding values can be used to monitor herd genetic differences and genetic trends within herds by averaging predicted values for cows born in the same year. Fig. 1 shows the overall genetic progress of cows' FCM yield in the sample of 1000 herds over a ten-year period with 1971 as the birth year of the oldest cows. A satisfactory 55.0 kg/year rate has been accomplished (JUGA 1985).

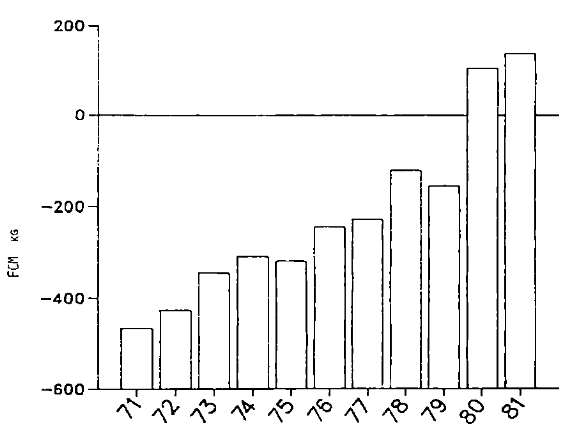

Fig. 1. The overall genetic progress of cows' FCM yield in a sample of 1000 Finnish herds over a ten-year period.

Evaluation and the use of MOET

Despite a late start in Finland the Multiple Ovulation and Embryo Transfer (MOET) in dairy cattle has produced successful results both in research trials and in practical conditions. The number of transferrable embryos per flushing is about 4 and the proportion of successful transfers around 60 % (V. RAINIO, personal communication). The use of embryo transfer in traditional progeny testing schemes has been found to contribute very little to the rate of improvement in national breeding programs. A more promising scheme was presented by NICHOLAS and SMITH (1983). They suggested the use of MOET in a nucleus breeding herd to improve the genetic merit of the herd, and to produce bulls to breed commercial cows in the national population. The genetic response possible in milk production was estimated to be from 30 to 79 % higher for various alternatives of an adult MOET scheme, compared to that theoretically possible with a conventional progeny testing scheme. On these grounds it was decided to study by computer simulation the effect of various selection schemes on a small MOET herd proposed for development in Finland (JUGA and MÄKI-TANILA 1987).

The genetic changes in milk production were studied in a nucleus herd, where 32 selected cows were mated with MOET to a different number of bulls. Eight progeny were generated from every mating with an equal number of each sex. Otherwise, the assumptions were the same as in NICHOLAS and SMITH (1983) so that for 256 progeny in a year, 512 transfers would be needed due to a 50 % success rate. The adult MOET scheme with a generation interval of 3.7 years was used in all cases. All of the effects, including sires' progeny test predictions, were generated from normal distributions.

For prediction of the breeding value of animals a modification of an intra-herd evaluation method (HENDERSON 1975b) was used. The model was an animal model with repeated records, incorporating sire evaluations. The evaluation of females was based on the cow's own first record and records of all available relatives, including the sire's evaluation. The number of mixed model equations was reduced by using the reduced animal model so that the equations of all culled animals were added into their parents' equation.

The results include two different alternatives, the original adult MOET and a scheme using adult MOET but including information from the progeny test of sires in outside herds. The genetic responses found were much lower than those predicted by NICHOLAS and SMITH (1983) (Table 1.) The differences between the simulation and the theoretical results may be due to the reduced selection differential because of the small number of families and the high intra-class correlation amongst family selection index values (HILL 1976). If a larger nucleus herd had been used in the simulation, the results might have been closer to the theoretical response. The small effect of the inclusion of field progeny testing on the accuracy of evaluation and on the genetic progress is probably due to the distance of the relatives, i.e. sires and grandsires, used in this way.

The use of MOET in a nucleus herd could be a method of choice in some countries where it is difficult to run the progeny testing scheme effectively. The effect of random drift in a small nucleus herd could be minimized by the use of an open nucleus. The genetic level of the nucleus could then be compared with the outside population and animals could be brought into the nucleus if they had better breeding values.

Table 1. The annual rate of genetic improvement over 8 generations of selection from 10 replicates of simulation in milk production (kg) of all nucleus bulls. A, an adult MOET scheme, B, an adult MOET including sires' progeny test information.

Scheme	4 sires 8 donors/sire		2 sires 16 donors/sire		1 sire 32 donors/sire	
	A	B	A	B	A	B
pred.						
%/year	1.78	—	2.03	—	2.24	—
simul.						
%/year	1.15	1.25	1.26	1.18	1.01	.88
kg/year	61	67	67	63	54	47

Pig Evaluation

Procedures based on best linear unbiassed prediction are widely used for genetic evaluation of dairy cattle and to some extent in beef cattle. It is only within the last couple of years that similar kinds of applications of genetic evaluation in pig populations have been made (e.g. HUDSON and KENNEDY 1985). However, we must remember that traditionally pig breeding has been based on station tests where a homogeneous environment favours the practicability of conventional selection indices. Even under such circumstances, there are some advantages available by more sophisticated methods. For example, the bias due to genetic progress could be removed by BLUP considering all the relationships between animals over the years.

A nationally supervised on-farm performance recording program was started in the mid-60's by the Finnish Animal Breeding Association; many farms also have records on sows' reproductive performance. So far, no information has been available on the genetic merit of the boar for reproductive traits. In Finland, a good 30 % of sows are inseminated, thus providing a firm basis for a national evaluation system.

An evaluation program was developed for reproductive traits (MÄKI-TANILA 1986). Gilt and sow traits were evaluated as separate traits. The former included age and litter size at the first farrowing, and the latter the litter size at subsequent farrowings as well as farrowing interval. The evaluation was computed for pigs whose both parents were identified considering all the relationships between animals. The procedure by SCHAEFFER and KENNEDY (1986) was applied as a computing strategy.

What are the advantages of this kind of evaluation system? First of all, accurate breeding value estimates are obtained for AI boars. This should enable successful selection for litter size and other reproduction traits. So far, the response has been obtained only as a consequence of an extensive screening of sows, whereas attempts to carry out selection in closed populations have failed. Traits could be combined into an index, e.g. piglet production per year. Secondly, by also providing evaluation for sows, breeding programs within a herd could be calculated, whether it means concentrating on the creation of dam lines or the improvement of an overall genetic level of sow prolificacy. The within-herd evaluations may be calculated more often by some simpler programs (c.f. AVALOS and SMITH 1987) which utilize the predicted values produced by the national evaluation.

Table 2 presents an example of trend analysis done for a sample of Landrace herds. As selection is more intense on production traits, we do not expect any genetic improvement in a reproductive trait. The averages are also listed for environmental or management performance. The period monitored prevents observation of any clear trend in either genetic or environmental averages.

The statistical model used for the reproductive traits in gilts is also an appropriate one for production traits, such as backfat and daily gain. The number of animals tested yearly at progeny/sib stations is only one-tenth of that tested on-farm. The implementation of an evaluation system for on-farm test records would enable the intensification of selection considerably or allow the broadening of the selection scope without any loss in the overall rate of improvement.

Utilization of dominance variation

It is known that when the variation in a trait is governed by a large number of loci or alternatively, by a locus with a large number of alleles without epistatic interaction and linkage disequilibrium between loci, and when the environmental deviations are independent of the genotypic values and normally distributed, we end up with a normal phenotypic distribution. Hence, linear methods are adequate. However, it is of interest to know how mixed model techniques behave when the genetic variation in a trait is due to a small number of loci with some of them acting in a non-additive fashion. Genes with considerable effects on a production trait have been found, e.g. halothane in pigs. Earlier studies (ROBERTSON 1977, BULMER 1980, MÄKI-TANILA 1982) suggest that in the relationship between breeding value

Table 2. The phenotypic average and the average of predicted breeding values for the size of 1st litter in a random sample of Landrace sows farrowed between January 1983 and September 1985.

Farrowing period	No. sows	Genetic trend	Environm. trend
Jan '83—July '83	63	.09	9.45
Aug. '83—Feb. '84	63	.10	10.12
Mar. '84—June '84	64	.04	9.77
July '84—Dec. '84	63	.09	10.01
Jan. '85—May '85	63	.06	9.70
June '85—Sep. '85	48	.07	9.64

and observation, the largest deviations from linearity follow when an allele at a major locus is rare and completely recessive and the proportion of overall genotypic variance is small.

The problem was approached by computer simulation by MÄKI-TANILA and KENNEDY (1986). The consequences of having genetic models with a small number of additive and non-additive loci were investigated allowing for phenotypic selection in one sex. A mixed linear model to include a dominance effect (c.f. HENDERSON 1985) was used together with the conventional individual animal model. In the analyses the true values for the variances were used.

In the way we considered the relationship between animals sharing the same allele, we can calculate the probabilities that animals have the same combination of alleles (dominance relationship). When there is no inbreeding, the construction of dominance relationship is simple (e.g. FALCONER 1981). In the analyses the relationship was computed by modifying the algorithm reported by SMITH and ALLAIRE (1985). Let us take individuals X and Y of which, say, Y is older with a sire S. If we denote by the subscripts m and p the alleles originating from dam and sire, respectively, we can form an allelic relationship for these individuals from the rule illustrated by an example

$$P(X_m = Y_p) = (P(X_m = S_p) + P(X_m = S_m))/2$$

By definition, the dominance relationship is then

$$P(X_p = Y_p)\, P(X_m = Y_m) + P(X_p = Y_m)\, P(X_m = Y_p)$$

In the case of dominance we obtain inbreeding depression. The analyses based on models having only the additive effect grossly underestimate the depression, while its estimates are better when the dominance effect is also considered. If we allow for selection, with complete addivitity we would expect that linear predictors would slightly over(under) estimate the response when the allele frequencies are high (low). The simulation results did support this, although the biases were fairly small. If the simulation had covered more than three generations of selection, the predicted response would have deviated more and not plateaued even after the selection limit had been reached. This bias is further augmented by dominance. In addition, when the recessive allele is very rare, most of the genetic variation is due to dominance, and because of inbreeding the response is depending on the direction of dominance either larger or smaller than the one predicted (HILL 1969). The addition of dominance value considerably improved the prediction of total genetic value.

If we have the right model and know the true parameters, the linear predictors work satisfactorily even if the number of loci governing the variation is very small. The only major exception is due to fixation. The accuracy of estimating dominance deviations can be improved by increasing inbreeding and thus creating more links between individuals over generations. The closest practical applications may be found in poultry breeding. As in another example of non-linearity, i.e. quadratic indices, the optimum way to utilize the dominance deviations might be to predict them for progeny from all possible mating pairs and perform selection on the outcome (c.f. JANSEN and WILTON 1985).

The main difference between selection index and mixed model prediction is the simultaneous estimation of environmental effects in the latter. In principle, selection index methodology could utilize the covariance structure between random effects to the same level of sophistication as BLUP, but this is rarely the case. The solution of overall computational difficulties along the simultaneous estimation of fixed effects has paved the way to techniques enabling more efficient use of information on all relatives. The selection index usually considers the records from only a few closest relatives covering at most three, and in any case, a small number of discrete generations. Ignoring the effect of the bias in the estimates of environmental, e.g. year factors it is relatively simple to calculate and compare the measures of accuracy for various alternatives of the selection index. The mixed model computing routines allow for an almost infinite depth in the relative information used for breeding value prediction. However, there is no general body of theory that allows the prediction of response to selection on genetic evaluations from mixed model methods that are based on information from all relatives, obtained over repeated cycles of selection with overlapping generations. In comparing the efficiency between the selection index and BLUP, we must use computer simulation, but we would still be in a difficult position to assess the importance of unbiassedness. The main issue lies in the theoretical and practical properties of mixed model methods to be able to accommodate a wide range of estimation and prediction problems.

Recently, suggestions have been made (e.g. NICHOLAS and SMITH 1983, AVALOS and SMITH 1987) which encourage the seeking of less conventional breeding strategies, or extension of the range of types of relatives considered in genetic evaluation systems. Traditionally, the emphasis has been on a straightforward progeny test type of evaluation with a pronounced unwillingness to use any information from lateral relatives. When we have useful amounts of full-sib and half-sib records available, as in pigs or, by superovulation and embryo transfer in cattle, we should look for the full utilization of that information even for less heritable traits. BLUP with an animal model is the most flexible tool to achieve this and offers the means to correct for common environmental (e.g. HUDSON and KENNEDY 1985) or for any non-additive genetic effects. The treatment of random factors other than breeding values would be very cumbersome to accomplish in the selection index procedure.

The full inclusion of pedigree information guarantees the proper adjustment for the genetic level of the previous and current generation. Furthermore, the recursive algorithm for the relationship coefficient connects animals over the whole generational span. Hence we can compare animals' breeding values over generations and monitor the effects of the selection decisions carried out. A linear genetic trend can be expected from a selection with equal intensity over the years. The failures to meet this cannot, however, all be explained by unrealized selection differentials. Whilst such logic is arguable for large practical breeding programs where the biological and statistical aspects are adequately verified, control populations and more objective interpretation are necessary in experimental situations.

When dairy sire evaluation was initiated, the solution of one problem almost by definition produced another. Selection practices previously had been rather inefficient due to the low accuracy of predictions. AI sires with 50—100 daughters would under the new circumstances have very reliable breeding value predictions and hence yield sound genetic improvement through a later crop of daughters.

After a few or even one cycle of selection, the assumption regarding random mating is distorted. The daughter of a test bull also reflects the genetic level of the dam used as a mate. All the discrepancies from random mating could be accounted for by the use of full pedigree information for bulls and by adjusting a daughter's record for her maternal grandsire's genetic level. A complete allowance for dam selection could be achieved using all the relationships between bulls and cows, i.e. using the individual animal model. In this case cow evaluation would be a straightforward by-product of sire evaluation.

KENNEDY (1988) has studied how the mixed model methods could be used to shorten the generation interval and hence increase the expected rate of selection response. Evaluation and appropriate culling could be done whenever a replacement were available. Such a culling procedure is not usually optimized because of the difficulties confounded between genetic and management effects. BELONSKY and KENNEDY (1988) found that the rate of genetic improvement could be considerably increased if culling decisions were based on a BLUP of genetic merit. Further improvements could be obtained using multi-trait analysis using various culling criteria as separate traits, e.g. first, second and third litter of sows.

Probably the most important advantage obtained through the use of the animal model is the very large increase in the number of animals evaluated under a uniform system. Evaluation strategies such as the sire reference scheme in various species, the progeny/sib test in pigs or the incorporation of a sire's proof in cow prediction do not utilize and conceal many such factors which have a crucial effect on across-herd comparisons between animals. It is always worth remembering that the breeding population which we are attempting to change in our effort to improve productivity, is formed by the animals scattered over the whole range of farms. To strengthen the basis of selection at the farm level and to increase the number of candidates for selection, i.e. the intensification of selection would benefit the whole production sector. An individual farmer would then also be able to closely monitor the effects of any changes in management or selection both within and throughout farms.

CONCLUSION

Animal breeding methodology is based on quantitative genetics which can be regarded as the synthesis of statistics and genetics. Quantitative genetics is concerned with the consequences of controlled modification of existing phenotypic variation in either plant or animal populations. In its classical form, as applied to animal breeding, it gives a statistical description of the genetic and environmental variation affecting a particular measurement in a given population at that moment and allows for some short-term predictions of response to selection. In essence, the introduction of only one new concept, that of heritability, provides a coherent framework into which different observations such as the effect of selection, or the similarity between relatives, can be fitted. Although the existence of segregating major loci may violate assumptions about normality, we have seen that linear methods provide satisfactory predictions for a wide range of genetic models.

Quantitative genetics has provided animal breeding with methods which can lead to steady and continued progress producing large economic returns at a relatively low cost. It is not necessarily easy to quantify what extra benefits to date have been derived from the use of BLUP in terms of increased rate of genetic improvement; although it is more likely to be several percent in most applications. The method has, however, given short-term genetic theory a natural framework and efficient properties. The basis of BLUP is so simple and its applications are so general as to make it a most elegant scientific structure and not only just a useful tool.

Our discussion has been focussed entirely in terms of quantitative genetics which, with regard to the recent advances of molecular genetics, might mistakenly be viewed as outdated technology. At this stage we must remain objective as to the potential value of DNA technology in animal breeding. As little imagination is required to foresee the enormous increases in genetic merit via genetic engineering techniques, it is probably better to rationalize some of the difficulties. A major problem is to identify a gene which is likely to lead to improvement. Considerable effort has been expended on blood groups as linked markers with little success. In retrospect, the general lack of success is hardly surprising, as there are so few blood group loci to span the whole genome. With the use of Restriction Fragment Length Polymorphisms (RFLPs) and minisatellites the whole genome can be closely mapped. Even if after such a localization we had a gene available, each insert in the recipient genome is random and unique. The animal obtained in this way — a transgenic — is thus the founder of a new 'breed' and would require much time and extensive resources for testing that no one should imagine improvement by gene transfer to be a quick and cheap process (SMITH 1987). We have to reassure ourselves that the changes by direct manipulation will increase economic performance above that achieved by selection on overall criteria and ask if the public is prepared to allow the production and consumption of transgenic animals. It is clear that breeders and producers have many opportunities to increase rates of genetic gain in animal production by applying existing as well as new knowledge. Competition both nationally and internationally will ensure that new opportunities are rapidly exploited.

Acknowledgements - Much of the work has stemmed from the co-operation with the Finnish Animal Breeding Association to which we are grateful.

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Manuscript received March 1988

Asko Mäki-Tanila and Jarmo Juga
Agricultural Research Centre
Department of Animal Breeding
SF-31600 Jokioinen, Finland

SELOSTUS

Yksilökohtaisten jalostusarvoennusteiden käyttö eläinten valinnassa

Asko Mäki-Tanila ja Jarmo Juga

Maatalouden tutkimuskeskus

Kotieläinalan tutkimus selvittää ja kehittää sellaisia uuden teknologian tarjoamia menetelmiä jotka entisestään parantavat kotieläintuotannon panos-tuotos -suhdetta. Tuottavuuden paraneminen johtaa halvempiin tuotteisiin ja vahventaa tuotantohaaran kilpailuasemaa. Eläinjalostuksen menetelmämuutosten vaatimat kustannukset ovat mittaviin etuihin verrattuna suhteellisen pieniä ja siten helposti toteutettavia. Olennainen osa kotieläinjalostustutkimusta on valintaohjelmien suunnittelu. Tietokoneiden kapasiteetin kasvu on yksilökohtaisen arvostelun avulla mahdollistanut valintapäätösten teon tiloilla olevista eläimistä. Eläinten jalostuksellisen arvon selittämisen pääongelma on ympäristöstä ja erilaisesta valinnasta johtuvien vaikutusten huomioonottaminen. Uusien tilastollisten menetelmien avulla voidaan poistaa myös vähäisemmät, emien valinnasta johtuvat arvosteluvinoudet. Kun kaikki eläimet arvostellaan samaa systeemiä käyttäen, laajenee vertailukelpoisten eläinten lukumäärä moninkertaiseksi. Tilatasolla mahdollinen valinnan ja ulkoisten tekijöiden antamien muutosten seuranta on yksi yksilökohtaisen arvostelun etuja. Sovellutusesimerkkejä ovat keinosiemennys- ja alkionsiirtojalostuksen yhteydessä toteutettu lehmien arvostelu sekä emakoiden ja karjujen hedelmällisyysarvostelu. Yksilökohtainen arvostelu voidaan laajentaa jalostusarvotyypistä kattamaan periytymisen erityisilmiöitä ja testaamaan myös siirrettyjen perintötekijöiden kokonaisvaikutusta.

ANNALES AGRICULTURAE FENNIAE, VOL. 27: 247—258 (1988)

Seria ANIMALIA DOMESTICA N. 86 — Sarja KOTIELÄIMET n:o 86

COMPARISON OF ENERGY FEEDING STANDARDS FOR GROWING CATTLE

1. RATIONS BASED ON DIFFERENT FORAGES

MARTTI LAMPILA, ANGEL MICORDIA and HANNA VÄÄTÄINEN

LAMPILA, M. MICORDIA, A. & VÄÄTÄINEN, H. 1988. **Comparison of energy feeding standards for growing cattle. 1. Rations based on different forages.** Ann. Agric. Fenn. 27: 247—258. (Agric. Res. Centre, Dept. Anim. Husb. SF-31600 Jokioinen, Finland.)

In a feeding trial with growing Ayrshire bulls, energy intake was compared with the estimated requirements according to each of five standards: two used in Great Britain (ARC and MAFF), based on metabolic energy, and three based on net energy as used in The Netherlands (DUTCH), in the German Democratic Republic (DDR) and in Finland (FU). Comparisons were based on net energy for which reason the intake was calculated as net energy in the British standards. The megajoule was used as a common unit of energy.

The results are based on data derived from a feeding experiment with 48 growing Ayrshire bulls with a mean age of 141 d at the beginning and 432 d at the end. The experiment, previously published elsewhere, was arranged factorially (2×4) to compare 4 forages: grass silage (GS), whole-crop barley silage (BS), hay (H) and oat straw (OS) at 2 levels (40 and 50 g/$W^{0.75}$) of concentrate supply. Only the grouping according to forage is dealt with here.

The Finnish standard is set out in tabulated form and only gives the total daily requirement in fattening feed units (FU). Therefore, for comparative purposes an equation was developed to replace the table. It is:

$$FU/d = 0.78348 + 0.002649 \cdot W + 0.6216 \cdot LWG + 0.01017 \cdot W \cdot LWG$$

where W = weight of animal and LWG = daily liveweight gain, both in kilograms.

When 85 kcal/$W^{0.75}$ was reserved for maintenance, the following equation for total daily net energy requirement was derived:

$$NE\ (kcal/d) = 85 \cdot W^{0.75} + LWG\ (1215.732 + 15.926 \cdot W) - 7.694 \cdot W$$

For the calculations, the weights and weight gains were taken from a separate best-fit regression equation calculated from the results of weighings for each animal. The same procedure was used in the calculation of energy intake on the basis of 2-week experimental periods. Additional comparisons were made by "correcting" weights, weight gains and regression equations to correspond to 50 % of carcass weight.

With the exception of the OS group, the line describing energy intake was, in all comparisons, more curved than that for the estimated requirement. In case of the OS

group, the bulkiness of straw apparently limited intake in the middle phase of the experiment more than that of the other forages, thus straightening the line.
For four of the standards, the difference between the total energy intake and experiment more than that of the other forages, thus straightening the line.
For four of the standards, the difference between the total energy intake and estimated requirement was at best within the limits of error for three of the groups. For the ARC standard, this was the case when calculations were based on original of calculation. In the MAFF standard the difference was significant in 3 groups independent of the method of calculation employed.

Index words: forages, growing bull, energy standards, feeding standards.

INTRODUCTION

Energy feeding standards for growing cattle have recently been renewed in Finland on the basis of data collected from domestic and foreign sources (SALO et al. 1982). Since then, however, results of several feeding experiments have indicated the need for further checking of the standards applied for growing and fattening animals raised for beef production. This need is accentuated by the fact that animals of the Ayrshire breed are common in Finland but not in the countries in which new feeding standards have recently been developed. The same is true with regard to feed evaluation based on Kellner's system used in Finland but which is not applied in foreign standards selected for the present comparisons.

The results of calculations presented here are based on data obtained from a feeding experiment with growing Ayrshire bulls in which grass silage, whole-crop barley silage, hay and oat straw were compared as the only forage at two levels of concentrate supply (LAMPILA et al. 1987). The foreign standards used in the comparisons were those applied or recommended in the German Democratic Republic, The Netherlands and Great Britain (2). Since the results presented here are from one of a series of experiments, there is no reason for generalizations at this stage.

EXPERIMENTAL METHODS

Animals and feeding

As described in a previous paper (LAMPILA et al. 1987), 48 Ay bull calves were grouped according to a 2 × 4 factorial design and fed individually. Their average age at the beginning was 141 days and at the end 432 days. Concentrate was given at two levels, 40 g and 50 g per kg metabolic weight ($W^{0.75}$). Forages, grass silage (GS), whole-crop barley silage (BS), hay (H) or oat straw (OS) were fed *ad libitum* and their intake measured daily. The amount of concentrate was adjusted fortnightly according to liveweights. Barley meal, used as concentrate, was supplemented by 200 g soybean meal per head per day below the LW of 140 kg in all groups. Thereafter, a lower level of supplementation, (100 g) soybean meal and/or urea, was continued except in the GS group. Mineral, trace element and vitamin supplements were given to satisfy the requirements. Water was freely available.

Determination of weights and weight gains

Fortnightly weighings of the animals did not give satisfactory estimates of the daily live-weight gain (DLWG) between two weighings, apparently because of the variations in the fill of the alimentary tract and bladder. Therefore, the results of the weighings were regressed on time using the best-fit equation out of the following for each particular animal: first and second degree polynomial, exponential, logarithmic or power function. Weights and DLWGs derived in this way were used as "original" in the calculations.

The weight of the contents of the alimentary tract at slaughter varied — as a percentage of the LW — in the different forage feeding groups from about 8.7 (GS) to 17.1 (OS) (LAMPILA et al. 1987). Thus, the DLWG appeared to be a relatively poor indicator of the "true" growth, when comparing the different forage feeding groups. Therefore, an attempt was made to improve the comparisons in complementary calculations by transforming the weight of an animal and, accordingly, DLWG onto the dressing out level of 50 %. Deviation from this percentage at slaughter was evenly distributed throughout the experimental time. The best-fit weight equations were adjusted accordingly and used to give the "corrected" weights and DLWGs.

Calculation of the energy value of feeds and feed rations

The analysis of feeds was carried out by the Weende method and the digestibility determined by wethers using the total collection method.

The energy contents of feeds and, accordingly, the energy requirements of the animals are expressed as net energy (NE) in the three systems compared, while metabolizable energy (ME) is used in the British systems. In order to have the same basis for the comparisons, ME was converted to NE by means of the equations presented in the two latter systems. The megajoule (MJ) was used as a common unit of energy. Equations used for calculations in the different systems were the following.

British ARC system

Equations used for the calculation of gross energy (GE) and ME of feeds, derived from SCHIEMANN et al. (1971), are presented in the publication of the Agricultural Research Council (abbr. ARC) (1980, p. 117) in the original form. The calculations for the efficiency coefficients k_m and k_f are shown on pages 80 and 84, respectively.

NEF system (DDR)

When applying this system, the net energy contents (in kcal) of the feeds were calculated using the equation 5.100 (Table 5.48, p. 145, SCHIEMANN et al. 1971). The gross energy and digestible energy (DE) needed for the correction factor in the equation were calculated by equations 5.4 and 5.26 (Table 5.42, p. 139, in SCHIEMANN et al. 1971), respectively. Calories were converted to joules by the same factor (4.184) as used in the British and Dutch systems.

DUTCH system

The equations used are according to VAN ES (1978). That for GE is no. 10, p. 334. Equation 6 was used for the ME of concentrates and straw, and Eq. 7 and Eq. 9 for the ME of hay and silage (p. 333). In the calculation of net energy, the efficiency coefficients k_m (Eq. 15) and k_f (Eq. 17) were used. The term q in the equations is $100 \times ME/GE$ (Eq. 12). The combination of k_m and k_f, k_{mf}, was calculated from

$$k_{mf} = (k_m \cdot k_f \cdot APL) / (k_m (APL - 1) + k_f)$$

In the calculation of APL, 100 kcal ME per kg metabolic weight, $W^{0.75}$, was expected (VAN ES 1978, p. 338).

Feed unit (FU) system

The system, as it is used in Finland, is based on Kellner's Starch Equivalents (S.E.) containing some modifications as described, e.g., by BREIREM and HOMB (1970, p. 10—14). It is based on 1 g digestible starch containing 2.36 kcal net energy for fattening (NK_F).

Calculation of the uncorrected S.E. value is carried out according to the following equation:

$$S.E. = 0.94 \cdot DCP + X \cdot DEE + DCF + DNFE$$

where DCP = digestible crude protein, g
DEE = digestible ether extract, g
DCF = digestible crude fiber, g
DNFE = digestible nitrogen free extract, g
X = 1 for DEE of silages, 1.91 for hay, 2.12 for cereals and 2.41 for oil seed and animal fats

The results obtained are corrected either by a value number or by crude fiber correction factors. In the present work, the value number 0.95 was used for the concentrate and 0.80 for silages. Crude fiber correction was used for hay and straw by subtracting 0.64 S.E. in the case of hay, and 0.58 S.E. in the case of straw per gram of crude fiber (CF) contained in the amount of feed under calculation.

After correction, the S.E.-sum was multiplied by 2.36 to obtain the NK_F-value of the feed portion. One FU equals 1650 NK_F for growth and fattening and 2000 NK_F for maintenance and milk production, respectively. Calorie values were converted to joules, in order to conform with the British and Dutch systems, by the factor 4.184. Since it is only 0.07 % smaller than the factor 4.1868 accepted later, the difference has no practical significance in the present comparisons.

British MAFF system

The equations applied were published in the Technical Bulletin 33 of the Ministry of Agriculture, Fisheries and Food (abbr. MAFF) (1976). The equation for ME is no. 2 on page 3. The efficiency with which ME is used for maintenance (k_m) and LW gain (k_g) is calculated by equations 5 and 8, p. 5 and 6, respectively. The term M/D, included in them, is defined as ME(MJ) per kg of DM. The combination of k_m and k_f, k_{mf}, is presented in Eq. 18, p. 10.

Calculation of the energy requirements

British ARC system

The equations for NE_m and NE_g, as derived from ARC, p. 118, were used in the forms

$$NE_m\ (MJ/d) = (0.53\ (W/1.08)^{0.67} + 15\ \%) + 0.0043 \cdot W$$

$$NE_g(MJ/d) = LWG\ (4.1 + 0.0332 \cdot W - 0.000009\ W^2)/(1 - 0.1475 \cdot LWG) - 15\ \%$$

NEF system (DDR)

The net energy requirement for maintenance (NE_m, kJ/d) was calculated using equations presented by HOFFMANN et al. (1981). Equation 4, p. 487, was used below LW 335 kg and 242 kJ per kg $W^{0.75}$ (from equation 7, p. 493) at and above that weight.

Net energy for LW gain, given by the same authors, is 8.5 MJ/kg gain for animals below 125 kg LW and then 8—10 MJ/kg up to 200 kg LW. Above the LW 200 kg equation 5, p. 488, was used. Between LWs 125 to 200 kg we used the following equation:

$$NE_g\ (MJ/d) = LWG\ (6.0 + 0.020 \cdot LW)$$

DUTCH system

The equation for NE_m (kcal/d) $= 100 \cdot k_m \cdot W^{0.75}$, derived from VAN ES (1978, p. 338), was applied. The equation 16 (VAN ES 1978, p. 338) was used for NE_g.

Feed unit (FU) system

The total net energy requirements of growing bulls expressed in fattening feed units are given in tabular form (SALO et al. 1982, p. 59). Because of the form, it was necessary to find equations to replace the table and to separate the requirements for maintenance and for LW gain in order to make comparisons possible with other systems. For this purpose, an approximation of 85 kcal per kg $W^{0.75}$ for maintenance, based on data presented by GABEL et al. (1985), was selected. Expressed in feed units, it calculates as 0.0425 FU per kg $W^{0.75}$. The equation calculated for the total FU requirement is:

$$FU/d = 0.78348 + 0.002649 \cdot W + 0.6216 \cdot LWG + 0.01017 \cdot W \cdot LWG$$
$$R^2 = 0.997,\ SE = 0.104$$

After subtraction of the maintenance from the total FU requirement the rest was accounted for by liveweight gain. The following equation for the energy requirement for gain was calculated using least squares analysis of multiple regression.

$$NE_g\ (kcal/d) = LWG\,(1215.732 + 15.926 \cdot W) - 7.694 \cdot W,\ SE = 0.548$$

British MAFF system

Equations 4, p. 9, with a 5 % safety margin, and 7, p. 6, given by MAFF (1976) were used for NE_m and NE_g, respectively.

RESULTS AND DISCUSSION

Weights, weight gains and feed intakes

As explained previously, the results of weighings were regressed on age using the best-fit equation for each animal. Weights derived from the equations were used for group means of the 2-week experimental periods shown in Fig. 1.

The DLWGs, calculated for each animal and period from the same equations, are presented in Fig. 2 as regressed group means.

Corresponding to the equations presented in Figures 1 and 2, the following equations were calculated on the basis of corrected liveweights.

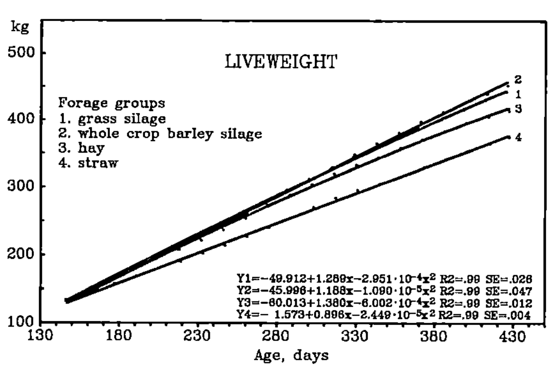

Fig. 1. Mean liveweights as a function of age.

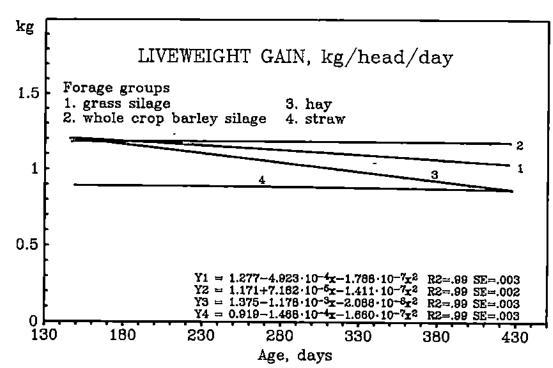

Fig. 2. Mean liveweight gains as a function of age.

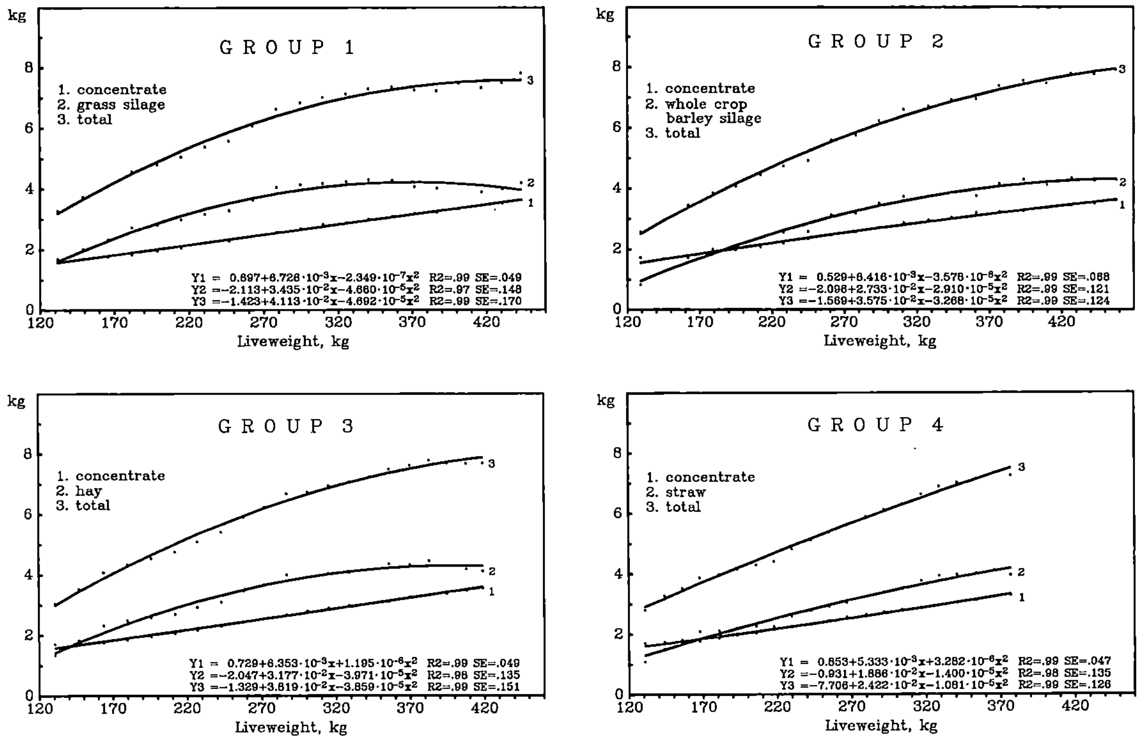

Fig. 3. Dry matter intakes as a function of liveweight.

Those for mean liveweights in groups 1—4 were:

Group 1 (GS) $Y_1 = -50.469 + 1.270 \cdot x - 1.360 \cdot 10^{-4} \cdot x^2$

Group 2 (BS) $Y_2 = -46.271 + 1.180 \cdot x + 5.447 \cdot 10^{-5} \cdot x^2$

Group 3 (H) $Y_3 = -61.089 + 1.382 \cdot x - 6.116 \cdot 10^{-4} \cdot x^2$

Group 4 (OS) $Y_4 = 0.247 + 0.911 \cdot x - 2.077 \cdot 10^{-4} \cdot x^2$

and for DLWGs:

Group 1 (GS) $Y_1 = 1.258 - 1.941 \cdot 10^{-4} \cdot x - 1.334 \cdot 10^{-7} \cdot x^2$

Group 2 (BS) $Y_2 = 1.152 + 3.118 \cdot 10^{-4} \cdot x - 3.551 \cdot 10^{-7} \cdot x^2$

Group 3 (H) $Y_3 = 1.374 - 1.155 \cdot 10^{-3} \cdot x - 1.288 \cdot 10^{-7} \cdot x^2$

Group 4 (OS) $Y_4 = 0.911 - 4.139 \cdot 10^{-4} \cdot x - 1.025 \cdot 10^{-8} \cdot x^2$

Dry matter intakes, total and separately from forage and concentrate, and regressed on LW, are shown in Fig. 3 as means for experimental periods (dots).

Feed intakes were regressed also on age. Integration of these equations between the beginning and end of the experiment gave exactly the same total intakes as direct calculation of the respective cumulative sums.

Comparison of the net energy intakes with estimated requirements

Fig. 4 is presented to illustrate typical differences between the systems of the calculated NE requirements for maintenance and weight gain, and that of their sums. In

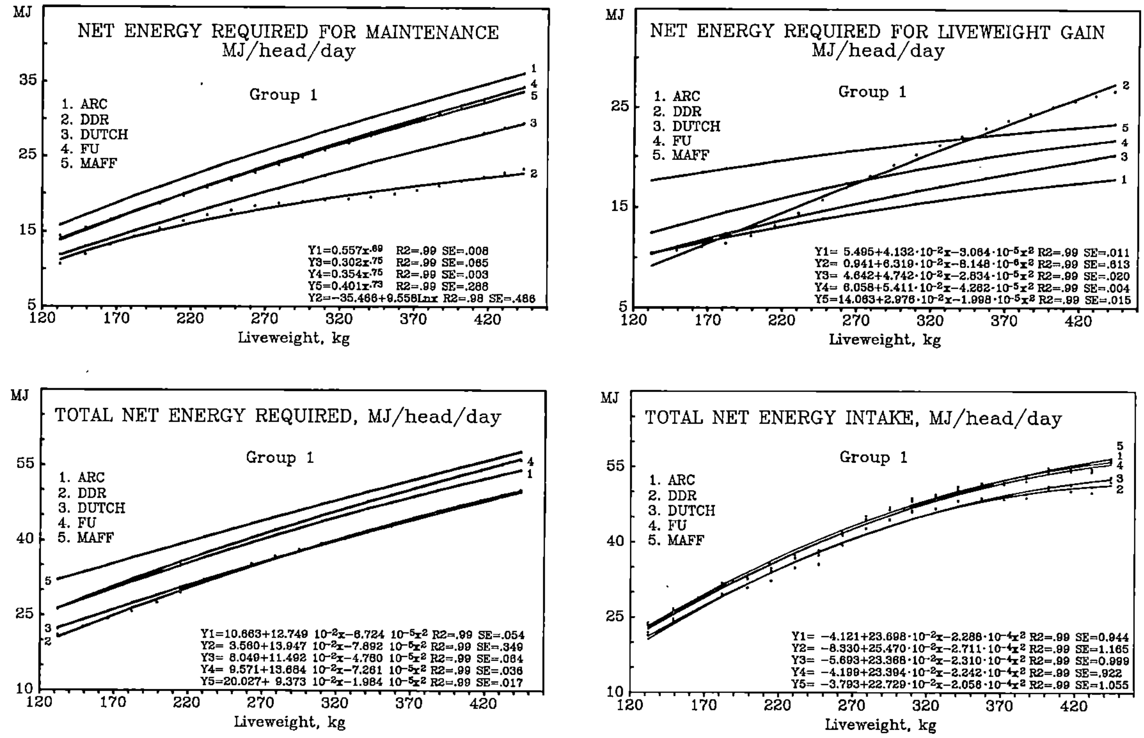

Fig. 4. Illustration of net energy requirements and intake as calculated according to different systems for experimental Group 1.

addition, comparison of the calculated net energy intake is also included.

The differences between the systems, especially in case of NE_m and NE_g, are partially quite large, indicating the difficulty in dividing the total NE requirement into its components. It should be pointed out, however, that no separation into NE_m and NE_g exists in the FU system applied in Finland. The method of separation applied was accepted only for the present work.

Fig. 5 shows the differences between the estimated daily NE requirements and intakes in different groups when the calculations were based on "original" liveweights. Equations for the curves are given in Appendix 1. The best-fit equation was a second degree polynomial in all cases. Percent differences were between the means of total requirements and intakes shown in Table 1. The significance of differences was tested by the F-test.

In all of the systems, a typical difference between the estimated requirement and measured intake is that the latter was more curved, except in group 4 with straw as forage. The reason for the difference was apparently due to the intake of forage (Fig. 3) which was fed *ad libitum*, while the supply of concentrate was determined by metabolic weight. In case of group 4, the bulkiness of straw was apparently the main factor modifying the shape of the increment in forage intake in relation to that occurring in other groups.

Another common feature was that the NE requirement exceeded the corresponding intake, although not always significantly, in groups 2 and 4 in all systems. In group 2 the reason may be a slight underestimation of the

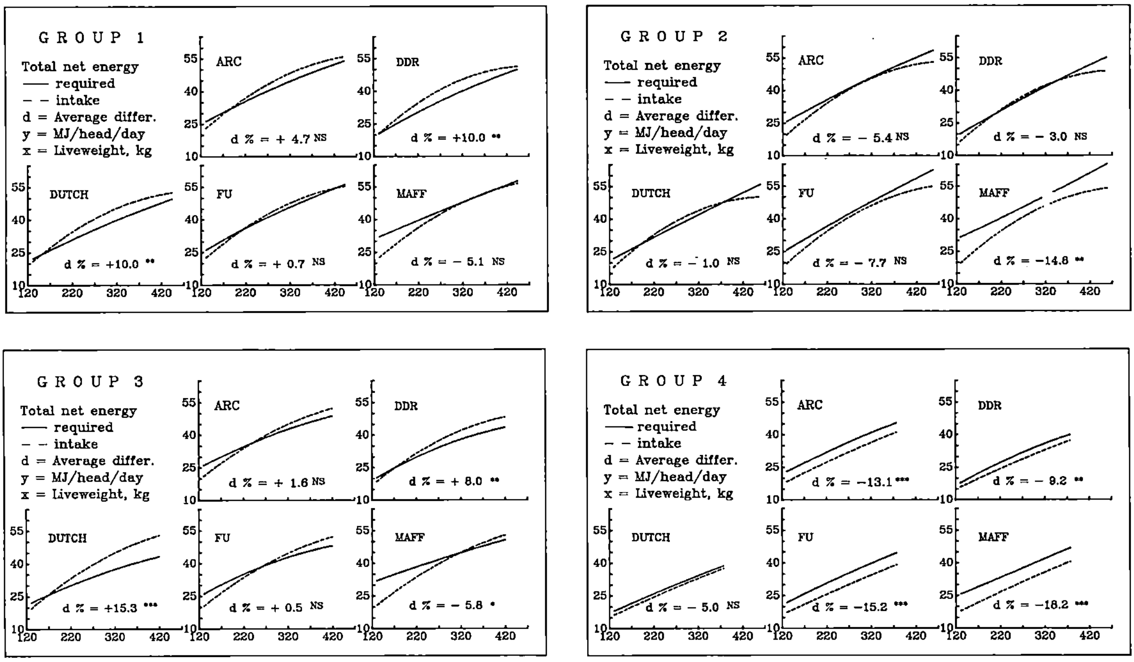

Fig. 5. Comparison of net energy requirement and intake in different experimental groups as calculated according to different systems.

value of barley silage. In Group 4, again, the reason for the difference apparently was the fact that relatively more gut contents was included in the liveweight and liveweight gain than in groups 1 and 2. When calculations were based on corrected liveweights (Table 1), the total energy requirements and differences between requirements and supply decreased. This illustrates the problem of how to take into account the effect of gut fill, both in the development and application of feeding standards, because a similar situation may be caused also by factors other than the quality of the forage.

In general, the conformity of energy requirements with respective intakes appeared to be quite satisfactory considering that the animals in this comparison were of another breed than those used in the development of foreign standards. Perhaps, however, the MAFF system may be considered as an exception because, according to it, the energy requirement exceeded intake in all groups (Table 1). In addition, the difference was significant in three cases out of four independent of the weight correction. The latter seems to have improved the result clearly in case of the DDR system by reducing the significant differences from three to one. A similar trend was observed in the DUTCH system, while in the ARC system the trend is in the opposite direction.

Acknowledgements — The authors wish to express their sincere thanks to Mr. J. Öfversten, Head of the Computing Service for mathematical advise and to Mr. J. Härmä, ADP-Designer of the Computing Service, for his technical assistance.

Table 1. Means of total net energy intake in MJs during the experiment compared with requirement as calculated on the basis of "original" and corrected liveweights.

SYSTEM	ARC	DDR	DUTCH	FU	MAFF
			ORIGINAL		
Group 1					
Intake	12640^{a}	11764^{a}	11846^{a}	12488^{a}	12545^{a}
Requirement	12070^{b}	10699^{a}	10774^{a}	12397^{bc}	13225^{c}
Difference	570 NS	1065 S	1072 S	91 NS	−680 NS
Group 2					
Intake	11778^{ab}	10790^{a}	11273^{ab}	11970^{b}	11888^{ab}
Requirement	12449^{ab}	11124^{a}	11383^{a}	12974^{b}	13916^{b}
Difference	−671 NS	−334 NS	−110 NS	−1003 NS	−2028 S
Group 3					
Intake	11581^{b}	10735^{a}	11486^{b}	11486^{b}	11569^{b}
Requirement	11401^{b}	9939^{a}	9960^{a}	11425^{b}	12278^{b}
Difference	180 NS	796 S	1526 S	61 NS	−709 S
Group 4					
Intake	8785^{b}	7866^{a}	7932^{a}	8300^{ab}	8611^{ab}
Requirement	10110^{b}	8666^{a}	8349^{a}	9793^{b}	10532^{b}
Difference	−1325 S	−800 S	−417 NS	−1493 S	−1921 S
			CORRECTED		
Group 1					
Intake	12675^{b}	11764^{a}	11718^{a}	12513^{ab}	12593^{ab}
Requirement	12641^{ab}	11330^{a}	11508^{a}	13210^{bc}	14097^{c}
Difference	34 NS	434 NS	210 NS	−697 NS	−1504 S
Group 2					
Intake	11793^{ab}	10790^{a}	11225^{ab}	11981^{b}	11908^{ab}
Requirement	12691^{abc}	11388^{a}	11704^{ab}	13315^{bc}	14296^{c}
Difference	−898 S	−598 NS	−479 NS	−1334 S	−2388 S
Group 3					
Intake	11579^{b}	10735^{a}	11495^{b}	11484^{b}	11565^{b}
Requirement	11380^{b}	9918^{a}	9945^{a}	11395^{b}	12258^{b}
Difference	199 NS	817 S	1550 S	89 NS	−693 NS
Group 4					
Intake	8715^{b}	7866^{a}	8107^{ab}	8266^{ab}	8526^{ab}
Requirement	9500^{c}	8034^{ab}	7711^{a}	8933^{bc}	9738^{c}
Difference	−785 S	−169 NS	396 NS	−667 NS	−1212 S

Figures for intake and requirement in the same row without a common superscript letter differ significantly ($P < 0.05$) according to Tukey's test. In the case of differences between intake and requirement, S = significant and NS = not significant.

Appendix 1

Net energy intake and requirement as best-fit second degree polynomial functions of "original" liveweights ($NE = a + bW + cW^2$); calculated according to different systems.

Group/System	REQUIREMENT a	REQUIREMENT b	REQUIREMENT c	SE	INTAKE a	INTAKE b	INTAKE c	R^2	SE
Group 1									
ARC	10.663	$12.749 \cdot 10^{-2}$	$-6.724 \cdot 10^{-5}$	0.054	−4.121	$23.698 \cdot 10^{-2}$	$-2.288 \cdot 10^{-4}$	.992	0.944
DDR	3.560	$13.947 \cdot 10^{-2}$	$-7.892 \cdot 10^{-5}$	0.349	−8.330	$25.470 \cdot 10^{-2}$	$-2.711 \cdot 10^{-4}$	.987	1.165
DUTCH	8.049	$11.492 \cdot 10^{-2}$	$-4.780 \cdot 10^{-5}$	0.064	−5.693	$23.368 \cdot 10^{-2}$	$-2.310 \cdot 10^{-4}$	.990	0.999
FU	9.571	$13.684 \cdot 10^{-2}$	$-7.261 \cdot 10^{-5}$	0.036	−4.199	$23.394 \cdot 10^{-2}$	$-2.242 \cdot 10^{-4}$	.992	0.922
MAFF	20.027	$9.373 \cdot 10^{-2}$	$-1.984 \cdot 10^{-5}$	0.017	−3.793	$22.729 \cdot 10^{-2}$	$-2.056 \cdot 10^{-4}$	.991	1.055
Group 2									
ARC	10.359	$12.547 \cdot 10^{-2}$	$-4.498 \cdot 10^{-5}$	0.073	−8.034	$24.607 \cdot 10^{-2}$	$-2.459 \cdot 10^{-4}$	.994	0.832
DDR	3.844	$13.172 \cdot 10^{-2}$	$-4.359 \cdot 10^{-5}$	0.359	−11.421	$25.038 \cdot 10^{-2}$	$-2.592 \cdot 10^{-4}$	.993	0.899
DUTCH	7.919	$11.092 \cdot 10^{-2}$	$-1.324 \cdot 10^{-5}$	0.084	−11.143	$26.122 \cdot 10^{-2}$	$-2.780 \cdot 10^{-4}$	.992	0.961
FU	9.408	$13.079 \cdot 10^{-2}$	$-3.244 \cdot 10^{-5}$	0.068	−7.980	$24.279 \cdot 10^{-2}$	$-2.295 \cdot 10^{-4}$	.995	0.788
MAFF	19.434	$9.069 \cdot 10^{-2}$	$1.936 \cdot 10^{-5}$	0.047	−8.260	$24.712 \cdot 10^{-2}$	$-2.428 \cdot 10^{-4}$	.994	0.865
Group 3									
ARC	10.990	$12.779 \cdot 10^{-2}$	$-8.943 \cdot 10^{-5}$	0.053	−2.884	$20.742 \cdot 10^{-2}$	$-1.806 \cdot 10^{-4}$	.995	0.719
DDR	2.818	$15.133 \cdot 10^{-2}$	$-1.295 \cdot 10^{-5}$	0.384	−6.181	$21.703 \cdot 10^{-2}$	$-2.073 \cdot 10^{-4}$	.992	0.846
DUTCH	8.699	$11.331 \cdot 10^{-2}$	$-7.316 \cdot 10^{-5}$	0.059	−6.168	$22.159 \cdot 10^{-2}$	$-1.924 \cdot 10^{-4}$	.993	0.899
FU	9.367	$14.475 \cdot 10^{-2}$	$-1.248 \cdot 10^{-4}$	0.025	−3.615	$20.863 \cdot 10^{-2}$	$-1.799 \cdot 10^{-4}$	.995	0.740
MAFF	21.839	$8.211 \cdot 10^{-2}$	$-3.157 \cdot 10^{-5}$	0.019	−2.697	$20.142 \cdot 10^{-2}$	$-1.638 \cdot 10^{-4}$	.995	0.703
Group 4									
ARC	8.597	$11.715 \cdot 10^{-2}$	$-5.104 \cdot 10^{-5}$	0.032	3.955	$11.671 \cdot 10^{-2}$	$-4.811 \cdot 10^{-5}$	.996	0.429
DDR	1.499	$13.694 \cdot 10^{-2}$	$-9.233 \cdot 10^{-5}$	0.276	2.021	$11.214 \cdot 10^{-2}$	$-4.902 \cdot 10^{-5}$	.993	0.561
DUTCH	5.982	$9.626 \cdot 10^{-2}$	$-2.439 \cdot 10^{-5}$	0.041	2.916	$10.706 \cdot 10^{-2}$	$-4.011 \cdot 10^{-5}$	.993	0.552
FU	7.900	$11.238 \cdot 10^{-2}$	$-3.931 \cdot 10^{-5}$	0.029	4.621	$10.064 \cdot 10^{-2}$	$-2.311 \cdot 10^{-5}$	.998	0.335
MAFF	14.474	$8.478 \cdot 10^{-2}$	$3.133 \cdot 10^{-6}$	0.009	4.440	$10.763 \cdot 10^{-2}$	$-3.064 \cdot 10^{-5}$	.997	0.391

Appendix 2

Net energy intake and requirement as best-fit second degree polynomial functions of corrected liveweights ($NE = a + bW + cW^2$); calculated according to different systems.

Group/System	REQUIREMENT a	REQUIREMENT b	REQUIREMENT c	SE	INTAKE a	INTAKE b	INTAKE c	R^2	SE
Group 1									
ARC	10.721	$12.785 \cdot 10^{-2}$	$-5.531 \cdot 10^{-5}$	0.060	−3.010	$22.715 \cdot 10^{-2}$	$-2.147 \cdot 10^{-4}$	.992	0.928
DDR	3.776	$13.668 \cdot 10^{-2}$	$-5.734 \cdot 10^{-5}$	0.333	−6.966	$24.242 \cdot 10^{-2}$	$-2.523 \cdot 10^{-4}$	.987	1.143
DUTCH	8.070	$11.557 \cdot 10^{-2}$	$-3.089 \cdot 10^{-5}$	0.069	−4.326	$22.162 \cdot 10^{-2}$	$-2.179 \cdot 10^{-4}$	.990	0.965
FU	9.772	$13.518 \cdot 10^{-2}$	$-4.818 \cdot 10^{-5}$	0.047	−3.068	$22.401 \cdot 10^{-2}$	$-2.103 \cdot 10^{-4}$	.993	0.904
MAFF	19.943	$9.763 \cdot 10^{-2}$	$-6.870 \cdot 10^{-6}$	0.017	−2.804	$21.855 \cdot 10^{-2}$	$-1.936 \cdot 10^{-4}$	.991	1.032
Group 2									
ARC	10.351	$12.608 \cdot 10^{-2}$	$-4.135 \cdot 10^{-5}$	0.072	−7.513	$24.130 \cdot 10^{-2}$	$-2.384 \cdot 10^{-4}$	.994	0.824
DDR	3.829	$13.167 \cdot 10^{-2}$	$-3.733 \cdot 10^{-5}$	0.354	−10.849	$24.520 \cdot 10^{-2}$	$-2.513 \cdot 10^{-4}$	.993	0.891
DUTCH	7.861	$11.209 \cdot 10^{-2}$	$-8.240 \cdot 10^{-6}$	0.085	−10.501	$25.537 \cdot 10^{-2}$	$-2.704 \cdot 10^{-4}$	.992	0.951
FU	9.407	$13.113 \cdot 10^{-2}$	$-2.503 \cdot 10^{-5}$	0.068	−7.462	$23.819 \cdot 10^{-2}$	$-2.230 \cdot 10^{-4}$	.995	0.781
MAFF	19.348	$9.323 \cdot 10^{-2}$	$2.243 \cdot 10^{-5}$	0.046	−7.710	$24.212 \cdot 10^{-2}$	$-2.349 \cdot 10^{-4}$	.994	0.856
Group 3									
ARC	10.969	$12.815 \cdot 10^{-2}$	$-9.087 \cdot 10^{-5}$	0.052	−2.906	$20.760 \cdot 10^{-2}$	$-1.806 \cdot 10^{-4}$	.995	0.720
DDR	2.627	$15.310 \cdot 10^{-2}$	$-1.336 \cdot 10^{-4}$	0.374	−6.205	$21.724 \cdot 10^{-2}$	$-2.074 \cdot 10^{-4}$	.992	0.848
DUTCH	8.724	$11.351 \cdot 10^{-2}$	$-7.438 \cdot 10^{-5}$	0.059	−6.180	$22.165 \cdot 10^{-2}$	$-1.917 \cdot 10^{-4}$	.993	0.901
FU	9.289	$14.558 \cdot 10^{-2}$	$-1.275 \cdot 10^{-4}$	0.022	−3.632	$20.877 \cdot 10^{-2}$	$-1.798 \cdot 10^{-4}$	.995	0.741
MAFF	21.919	$8.190 \cdot 10^{-2}$	$-3.233 \cdot 10^{-5}$	0.020	−2.712	$20.155 \cdot 10^{-2}$	$-1.638 \cdot 10^{-4}$	.995	0.705
Group 4									
ARC	8.659	$11.568 \cdot 10^{-2}$	$-6.525 \cdot 10^{-5}$	0.028	3.789	$11.605 \cdot 10^{-2}$	$-3.248 \cdot 10^{-5}$	.996	0.431
DDR	1.165	$14.109 \cdot 10^{-2}$	$-1.238 \cdot 10^{-4}$	0.249	1.813	$11.126 \cdot 10^{-2}$	$-2.890 \cdot 10^{-5}$	.993	0.564
DUTCH	6.107	$9.434 \cdot 10^{-2}$	$-4.018 \cdot 10^{-5}$	0.039	2.859	$10.396 \cdot 10^{-2}$	$-4.389 \cdot 10^{-6}$	.994	0.565
FU	7.952	$11.175 \cdot 10^{-2}$	$-6.975 \cdot 10^{-5}$	0.024	4.613	$9.783 \cdot 10^{-2}$	$8.107 \cdot 10^{-5}$	.998	0.335
MAFF	14.790	$7.866 \cdot 10^{-2}$	$-7.210 \cdot 10^{-6}$	0.007	4.314	$10.666 \cdot 10^{-2}$	$-1.500 \cdot 10^{-5}$	.997	0.394

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Manuscript received December 1987

Martti Lampila
Agricultural Research Centre
Department of Animal Husbandry
SF-31600 Jokioinen, Finland

SELOSTUS

Energianormistojen vertailu kasvavien Ayrshire-sonnien ruokintakokein

1. Eri korsirehuihin perustuvat dieetit

Martti Lampila, Angel Micordia ja Hanna Väätäinen

Maatalouden tutkimuskeskus

Energian saantia ja normin mukaista tarvetta verrattiin keskenään laskien ne viiden normiston mukaan. Normistot olivat: 2 Englannissa käytössä olevaa, muuntokelpoiseen energiaan perustuvaa (ARC ja MAFF) ja nettoenergiaan perustuvat Alankomaissa (DUTCH), Saksan Demokraattisessa Tasavallassa (DDR) sekä Suomessa (FU) käytettävät. Vertailu tehtiin nettoenergiaan perustuen, jota varten energian saanti englantilaisissa järjestelmissä muunnettiin nettoenergiaksi. Energian mittayksikkönä käytettiin kaikissa tapauksissa megajoulea.

Tulokset perustuvat 48 kasvavalla Ayrshire-sonnilla keskimääräisellä ikävälillä 141—432 päivää tehtyyn ruokintakokeeseen, jossa verrattiin keskenään nurmisäilörehua, kokoviljasäilörehua, heinää ja kauranolkea kahdella väkirehun annostustasolla, 40 ja 50 g metabolista elopainokiloa kohti. Viimemainittujen vaikutuksia ei käsitelty vertailussa, mutta niitä on rehuyksikköön perustuen tarkasteltu aikaisemmassa julkaisussa.

Suomalainen normisto on taulukkona ja esittää vain kokonaistarpeen. Vertailuja varten se muutettiin matemaattiseksi yhtälöksi ja tarve jaettiin ylläpidon ja kasvun osalle. Rehuyksikköinä (FU) ilmaistua päivittäistä koko energiatarvetta kuvaavaksi yhtälöksi saatiin

$$FU = 0.78348 + 0.002649 \cdot W + 0.6216 \cdot LWG + 0.01017 \cdot W \cdot LWG$$

jossa W = eläimen paino ja LWG = päiväkasvu, kumpikin kiloina. Kun ylläpitoon varattiin 85 kcal per kg $W^{0.75}$ päivässä ja nettoenergian tarve (NE) ilmaistaan kilokaloreina, sai yhtälö muodon

$$NE\ (kcal/pv) = 85 \cdot W^{0.75} + LWG\ (1215.732 + 15.926 \cdot W) - 7.694 \cdot W$$

Energian tarpeen laskemista varten eläinten paino ja painonkehitys laskettiin ns. "best-fit" yhtälöstä, joka määritettiin punnituksiin perustuen jokaiselle eläimelle erikseen. Samoin meneteltiin laskettaessa energian saantia 2-viikkoisiin koejaksoihin perustuen. Vertailua täydennettiin korjaamalla eläinten painot ja painonkehitys sekä regressioyhtälöt vastaamaan 50 prosentin teuraspainoa.

Lukuunottamatta olkea syönyttä koeryhmää, energian saannin kuvaaja oli kaikissa vertailuissa käyrempi kuin standardin mukaan lasketun tarpeen kuvaaja. Poikkeus oljen kohdalla johtui ilmeisesti sen suuresta täyttävyydestä, joka rajoitti syöntiä ja energian saantia koeajan keskivaiheilla suhteellisesti enemmän kuin muitten korsirehujen.

Neljässä järjestelmässä energian koko tarpeen ja saannin välinen ero oli virherajojen sisällä parhaimmillaan kolmessa koeryhmässä neljästä. ARC-standardissa näin oli laskettaessa tarve korjaamattomien painojen perusteella, DDR- ja DUTCH-standardeissa taas korjatuilla painoilla. Suomalaisessa (FU) standardissa sama tulos saatiin kummallakin laskutavalla. MAFF-standardissa ero oli laskutavasta riippumatta virherajan puitteissa vain yhdessä tapauksessa.

ERRATA

ANNALES AGRICULTURAE FENNIAE VOL. 27

MÄKI-TANILA, A. & JUGA, J. 1988. Use of the individual animal model in the genetic evaluation of breeding animals. Ann. Agric. Fenn. 27: 231-246.

On page 231 the last 3 rows on the right hand column should be:

demand. The production of almost all major
commodities now exceeds not only domestic
demand - by 10-35 % - but also the

LAMPILA, M., MICORDIA, A & VÄÄTÄINEN, H. 1988. Comparison of energy feeding standards for growing cattle. 1. Rations based on different forages. Ann. Agric. Fenn. 27: 247-258.

On page 248 the last 7 rows of the abstract should be:

For four of the standards, the difference between the total energy intake and estimated requirement was at best within the limits of error for three of the groups. For the ARC standard, this was the case when calculations were based on original weights, while for the DDR and DUTCH standards the same occurred with corrected weights. In the Finnish (FU) standard the same result was obtained by both methods of calculation. In the MAFF standard the difference was significant in 3 groups independent of the method of calculation employed.

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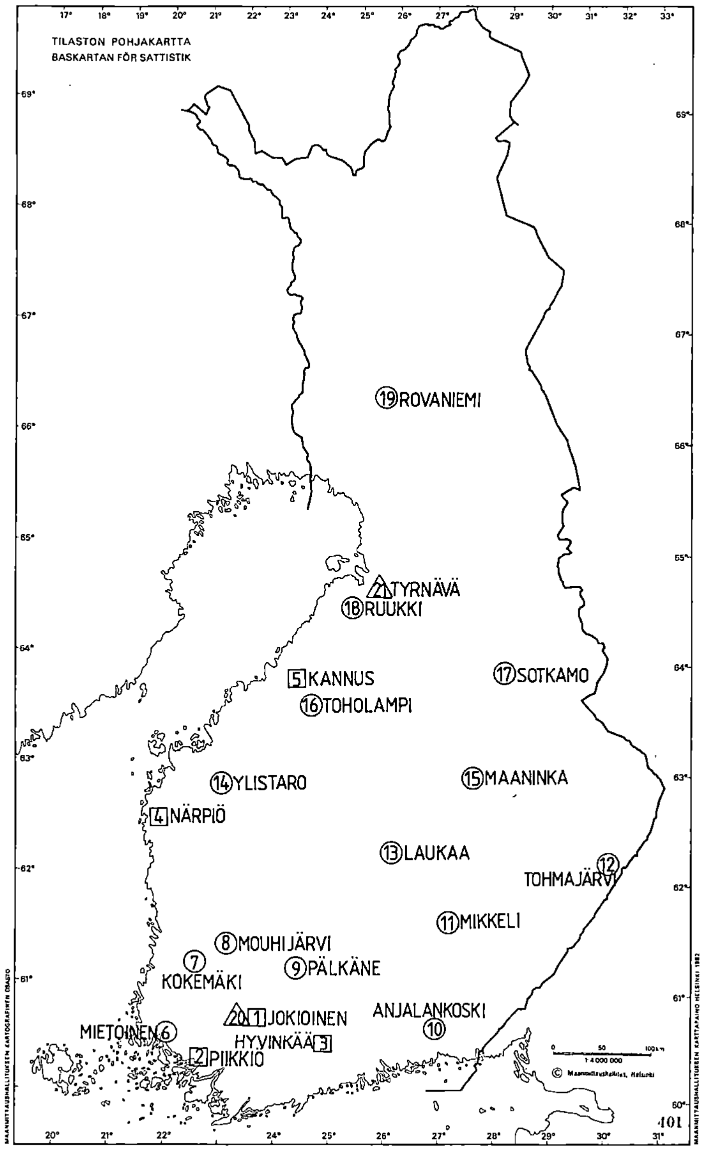

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SISÄLLYS — CONTENTS

Helsinki 1987. Government Printing Centre