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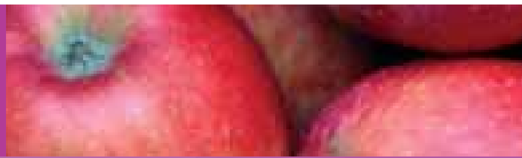
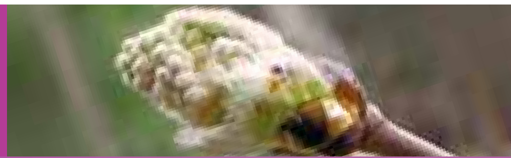

THE NEW NORDIC REGION

• knowledge • innovation • creativity

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Nordic Council of Ministers

Contents

Editors

Editor livestock
Morten Kargo Sørensen, Denmark
E-mail: morten.kargo@agrsci.dk

Editor crops
Katarina Wedelsbäck Bladh, Sweden
E-mail: katarina.wedelsback.bladh@nordgen.org

Editor forest trees
Leena Yrjänä, Finland
E-mail: leena.yrjana@nordgen.org

Chief editor
Liv Lønne Dille, Nordic Gene Bank Farm Animals
E-mail: liv@nordgen.org

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PHOTO: LIV LØNNE DILLE

Genetic Resources: an Important Part of the New Nordic Region

The world is constantly changing – and it actually requires quite an effort to keep oneself up-to-date. I'm thinking of such issues as international agreements, climate change and national strategies for how to cope with future challenges. It is important that the assessment of genetic resources is also included in these processes. We must not look at genetic resources as a 'dusty and boring' field of study, but rather as an exciting area with a tremendous potential. Our future depends completely on a diversity of genetic resources, but there seems to be quite a widespread lack of understanding for the profound significance of these resources. In my opinion, part of the problem is that those who are not involved in the management of genetic resources take genetic resources as a matter of course – which they unfortunately are not. Together, we must contribute to these efforts, no matter in what field we are working in. All aspects of primary production are in one way or another based on the earth's genetic resources, and we have to stand together to secure the diversity of these resources for the future.

The Norwegian Presidency of the Nordic Council of Ministers has titled its programme for 2006, "The New Nordic Region: Innovation and Partnership in Northern Europe". In its programme, the Presidency also announced that the organization of Nordic activities in the field of genetic resources is to be reviewed, with the aim of streamlining operations and improving Nordic cooperation. For us engaged in the management of crop, livestock and forest genetic resources, this clearly implies upcoming changes – and naturally we are hoping for a change for the better. The Nordic Gene Bank, the Nordic Gene Bank Farm Animals and the Nordic Council for Forest Reproductive Material have already worked together for several years, and we are witnessing increasing cooperation between the different sectors. NORDGEN has become our "umbrella". We now also realize that this collaboration can gradually be further extended, e.g., to involving project cooperation. Several ideas for joint projects are currently being developed.

Nordiske GENressurser would like to thank all authors of the articles in this edition of Nordiske Genressurser. As in previous years, it has been an easy task to find topics for the publication, and everyone we asked to contribute was immediately positive. We hope all of our readers will enjoy this year's edition. Among the diversity of topics, you can read about "Swedes in Iceland", the taste of heirloom plums and wild European apples and the story of how a native cattle breed is being revived to provide state-of-the-art designer products and tasty foods.

Ås 15 May 2006
Liv Lønne Dille
Editor

Nordic Cooperation on Genetic Resources

Birthe Ivars, Chairperson of the Nordic Genetic Resource Council, Norway, birthe.ivars@md.dep.no

Important activities are being conducted under the auspices of the Nordic Council of Ministers to conserve Nordic genetic resources. Due to their exchange of genetic resources and cooperation on managing these resources, the Nordic countries have a considerable share of their genetic resource base in common. In 2001, the Nordic Council of Ministers established the Nordic Genetic Resource Council to discuss and evaluate issues of strategic and political importance for the conservation and sustainable use of genetic resources. The Genetic Resource Council shall also act as the advisory body for the Nordic councils of fisheries, agricultural, forestry, food and environmental ministers. One of the goals of the Nordic Environmental Action Plan for 2005-08 states that: ”The Nordic countries will sustainably maintain and use genetic resources, and promote the fair sharing of the benefits derived from genetic resources”.

Norwegian Presidency 2006

The Norwegian Presidency has initiated an evaluation of the organization of Nordic activities in the field of genetic resources prior to the Minister Conference in July 2006. The process will include an assessment of how to possibly streamline activities and increase their efficiency. Another issue will be the division of responsibilities between Nordic and national as well as international agencies and organizations.

The Presidency also initiated another exciting project. The Norwegian government has decided to establish a global seed storage facility on Svalbard. The International Treaty on Plant Genetic Resources for Food and Agriculture commits the parties to ensure the conservation and sustainable utilization of such genetic resources. The treaty emphasizes the importance of preserving plant genetic resources for future generations. The Svalbard storage facilities thus represent an additional safety precaution, specifically with regard to gene banks located in areas threatened by natural disasters or social/political instability.

Svalbard is regarded as a highly suitable site for such an international seed storage bank. The storage facilities will be established in permafrost, and be further cooled to -18°C. The proposal of using Svalbard for seed safety storage was approved by the FAO, and the site will become part FAO’s global system for the conservation of plant genetic resources.

International initiatives

The Nordic joint efforts in the field of genetic resource management have aroused international interest. There have been international initiatives to further develop the Nordic approach in connection with the follow-up of genetic resource issues under the Convention on Biological Diversity (CBD), the FAO and the EU. The aim is to support the utilization of Nordic experience and know-how as a common base for the development of Nordic platforms within relevant fields related to animal health, food safety and food quality.

The Nordic Genetic Resource Council focuses on spreading information about Nordic efforts in the field of genetic resources, e.g., by arranging so-called ”side events” at Conferences of the Parties under the CBD and the FAO Treaty on Plant Genetic Resources. The last such side event was hosted at the eighth Conference of the Parties to the CBD in Curitiba, Brazil in March 2006. One of the main issues of the Conference was access to and fair sharing of genetic resources.

The link to international negotiations

A Nordic seminar will be arranged in the autumn of 2006 to inform users of genetic resources, i.e., industry, universities, research institutes, etc., of the so-called Bonn Guidelines (international guidelines established under the CBD). These guidelines shall assist countries in developing national policies and legislature in the field of biodiversity. It is also important to inform about ongoing negotiations under the CBD and the FAO treaty. The current CBD negotiations deal with establishing an international regime for the access to genetic resources and the fair and equitable sharing of benefits. The goal is to finalize negotiations in 2010. The Nordic Genetic Resource Council can contribute to this process. One of the issues of the Council’s work programme for 2006 is to review the concept of “fair and equitable benefit-

PHOTO: LIV LØNNE DILLE

sharing". It is important to develop methodologies and mechanisms that enable the achievement of the CBD's third objective, i.e., fair and equitable sharing of benefits. Equitable sharing of benefits will also motivate and provide an incentive for developing countries to preserve their biological diversity.

New activities

One of the Nordic Genetic Resource Council's new activities is the development of a policy for dealing with GMO material in the Nordic Gene Bank (NGB). This issue should be managed by the NGB. There are many aspects to be considered: what policies should we have regarding the storage of GMO material in the Nordic Gene Bank and how do we deal with the possible unintentional contamination with GMOs? Such a policy should provide the basis for developing more detailed guidelines for dealing with GMO material in the gene bank.

The Council shall furthermore evaluate any Nordic contributions to the international trade with GMOs. This work is linked to the implementation of the Cartagena Protocol on Biosafety, especially with regard to risk assessment methods and the negotiation of rules for liability and redress for damage resulting from transboundary movements of living modified organisms.

Future regulation of farm animal genetic resources is another area that will receive increasing attention. So far, not much work has been done in this field, and in the years ahead one faces many scientific and political challenges. With its expertise in the field, the Nordic countries can contribute to this process, which will have national and international consequences. In cooperation with the livestock sector, the Nordic Genetic Resource Council initiated an assessment of how farm animal genetic resources can be regulated in the Nordic countries. This project can be linked to the ongoing process in the FAO regarding the need for international regulation of farm animal genetic resources.

In the future, we will attempt to include the fishery sector in the Nordic work on genetic resources. It seems highly probable that bioprospecting activities and value creation in the field of marine genetic resources is going to increase in the future. One of the reasons for this prognosis is that the biotechnological capacity for utilizing these resources has been improved. A lot of challenges lie ahead!

Self-rooted Plum Varieties in Norway

Stein Harald Hjeltnes, Researcher, Bioforsk Njøs, Norway, stein.harald.hjeltnes@bioforsk.no

Throughout the years, several self-rooted plum varieties have been cultivated in Norway. The best known of the high-grade types are 'Reine Claude Green', which no longer is being grown commercially in Norway, and local varieties with known origin, such as the 'Tråne plum' – a variety that was raised from seed and later propagated from root suckers. However, most widespread are various types of old yellow, blue, red and green plums – varieties that nowadays receive little attention. It is often believed that these trees grew from root suckers that were left standing in old plum orchards. This may well be the case, but what are the origins of these original trees?

It is generally thought that Alexander the Great brought plums to Greece around 330 BC, probably from Damaskus in Syria. Hence the name damson ("damasker" in some parts of Norway). Damsons belong to the group of native European plums, Prunus insititia. In German, these fruits go by a variety of names, such as 'Haber Pflaume', 'Kreke', 'Krieche', 'Sankt-Julians Pflaume' and 'Zipperle'. In Denmark they are known under such names as 'Havreblomme' and "Spillinge blommer". In England and the USA, 'damson' is used for oval, black plums, whereas rounder plums of this type are called 'bullaces' in England. Continental Europe does not define damsons as strictly, and in Norway, for example, 'damask' has also been used for small yellow plums, whereas the term 'kreke' usually is linked to dark-coloured plums. These plums are thus small plums originating from the hexaploid species P. insititia. In Germany and Switzerland, old stones of this species have been found, showing that the trees were already cultivated in the early Stone Age. The species also includes many of the excellent rootstocks belonging to the St. Julien group and Damas, as well as the mirabelles. Damsons were introduced to Norway quite early, and are thus varieties of the types otherwise found in northern Europe. Damsons are considerably better adapted to cultivation in cool climates than prunes. Whereas most prune varieties do not fully ripen in a cool climate, damson trees are extremely hardy, produce lots of fruit-bearing shoots and are especially suited for processing.


PHOTO: STEIN H. HJELTNES

A blue plum in Ulvik along the Hardanger Fjord.

Self-rooted plum varieties have been extensively used as rootstocks, and were also often grown in household gardens and sold as table fruit. It is known that both blue and yellow sweet plums were previously sold as table fruit in various parts of Norway. Major rootstock types included "Yellow plums", or "Yellow sugar plum", which were widely used in the Hardanger and Sogn regions (western fjords), and the "Ombo plum", which was popular in Rogaland (south-western Norway). Many of these local plum types did well in the rootstock trials established at Njøs in 1952. Numerous local varieties were collected for these trials in the late 1940s, including "Winter plum", "Sugar plum", "Red plum", "Blue plum", "Ombo plum" and "Berga plum". The main problem associated with such local rootstocks was their prolific suckering. It has thus been quite a while since plum trees with these rootstocks have been produced.

There have been very few thorough studies of old, self-rooted plums in Norway, and in many ways, plums have been a neglected species. The trees usually occur as thickets near farmyards, in old fences and stone piles, where they often have been neglected for decades. Since it has become common to buy imported clonal rootstocks of selected types of plums, the production of rootstock from the old plum types has also ceased. Pomological descriptions of the old plums are also scarce, but the "Blue plum" and "Yellow plum" were

Four different self-rooted plum types collected in Leikanger on 10 September 2005. Yellow sugar plum, red plum and two types of blue plums.

PHOTO: STEIN H. HJELTNES

described in Norsk Hagetidend (Norwegian Horticultural Journal) by Birkeland and Skard in the 1920s. Old fruit farmers are convinced that 'Oullins' had better quality when grafted on local rootstocks such as "Ombo plum" and "Yellow sugar plum", but this has not been shown in trials. Some of the self-rooted plums found in Norway are briefly described below.

"Vanleg gulplomme" (Common yellow plum)
This is presumably the most widely grown type of yellow plum in Norway. "Vanleg gulplomme" ripens around mid-September, and the fruit is light yellow with bloom, has firm, yellow flesh and is more or less freestone. The trees are extremely hardy and are good croppers.

"Gul sukkerplomme" (Yellow sugar plum)
This is a small, sweet, egg or grape-shaped plum, and is probably the same plum that has been known in England since the 700s under various names, such as 'Early Yellow' and 'Prune d'Avoine'. The flesh is loose, course, juicy, light yellow, sweet and slightly aromatic, and also freestone. The vigorous, downy shoots are also typical for this variety, which is widely grown throughout Norway.

"Omboplomme"
A local variety of yellow damsons from Ryfylke in south-western Norway. "Omboplomme" used to be widely used as a rootstock, especially for "Sandeplomme" ('R.Cl. d'Oullins') and 'R.Cl. d'Althanns'. The rootstocks were grown from seed, which was also common for several other types of damsons, e.g., 'St.Julien'. All of these gave relatively uniform offspring, but lots of root suckers. The plums ripen late and are bitter, but become much sweeter after a touch of frost.

"Blåplomme" (Blue plum)
This common blue plum is also widely grown in Norway, but must not be confused with 'River's Early Prolific'.

"Blåplomme" has oval or round fruit with a thin stalk. The plums have a good quality, and used to be widely sold as table fruit. Written and oral sources indicate that there are several types of blue plums in Norway, and some of these are presumably damsons. The Norwegian clone archives contain several blue plum types, often with local names based on their site of collection.

"Raudplomme" (Red plum)
These can also be found at several sites in Norway, but are less common than the yellow and blue types. "Raudplomme" has small, round, sweet and tasty plums that are freestone. The red plums found in Leikanger in 2005 ripened in early September, and had many of the same characteristics as the Swedish 'rödplommon' (as described by Eneroth).

Green plums
Green plums are the least widespread type of plum in Norway. So far, they have only been found in the Hardanger and Sogn regions. They are locally known as "Winter plums" in Sogn, as they only are edible after a touch of frost. The plums are about the same size as 'Green Gage' and almost transparent. The trees often grow quite tall, forming dense stands from numerous root suckers.

Final remarks
Plum growing has longstanding traditions in Norway. Many of the self-rooted varieties found are clearly the same ones as can be found elsewhere in the Nordic and Baltic region. However, due to adaptations to local climate changes through the centuries, some varieties may have changed. It is thus not certain if all of the plum types found in Norway also can be found elsewhere in the Nordic countries, but modern technology could help to shed light upon such questions.

Jerusalem Artichokes in Denmark

Gitte Kjelsen Bjørn, Senior scientist, Danish Institute of Agricultural Sciences, gittek.bjorn@agrsci.dk

The Jerusalem artichoke is a perennial root crop, which presumably was introduced to Denmark in the late 1500s. Jerusalem artichokes were widely grown as a food crop until the 1800s, but were gradually replaced by the increasingly popular potato. Eventually, the cultivation and use of the Jerusalem artichoke declined significantly, as there was little focus on the crop's potential or alternative uses.

PHOTO: GITTE KJELSEN BJØRN

Helianthus tuberosus L.

Cultivation

In Denmark, Jerusalem artichokes are grown as a garden crop. The tubers are sold as a delicacy, often at 3-5 times higher prices than potatoes. However, the cultivation and post-harvest treatment of the crop is quite labour-intensive. Production costs are thus high, and the total market turnover is relatively modest.

In recent years, though, the demand for Jerusalem artichokes has increased. As a result, there is renewed interest in the crop's cultivation, especially with regard to organic production. No statistics are available about the precise extent of the crop's cultivation, consumption or import/export. Denmark does not produce enough Jerusalem artichokes to meet domestic demands. The entire domestic yield of the crop is used for fresh consumption; there are currently no businesses that process Jerusalem artichokes.

Although a perennial plant, Jerusalem artichokes are commercially only grown as an annual crop. The tubers are set like potatoes. Since they are able to overwinter in the ground, the tubers can be planted in October or November, or even in mid-winter, weather and soil conditions permitting. However, tubers are generally planted in early spring. Seed tubers should be as smooth and well-formed as possible.

Varieties

The Danish Institute of Agricultural Science's horticultural research station at Årslev has a clone archive containing 17 landrace varieties/selections of Jerusalem artichokes. These clones are part of the Nordic collection of plant genetic resources for the species.

The Jerusalem artichoke is not included on the EU's list of certified vegetable varieties, since there are no UPOV guidelines, i.e., a list of characteristic traits for variety descriptions. The varieties at Årslev are described by their morphological traits, in accordance with a list developed in cooperation with the Nordic Gene Bank. In addition to the morphological descriptions, tubers from 15 of the stored varieties were analyzed for carbohydrate contents and composition.

Field trials and yield assessments have been performed with some of the varieties, but we lack data from the remaining varieties. Newer results about such aspects as health effects and taste are also scarce. For these reasons, the Danish Institute of Agricultural Sciences has been granted funds for the project ”Promoting Danish-grown Jerusalem artichokes”. The project started in January 2006, and will study the varieties in the clonal archive, comparing them to varieties known to today's growers, as well as one variety from Sweden and one from Norway.

Expected results

Results from the Danish Jerusalem artichoke project will be extremely important for the further development of the crop in Denmark. How does the choice of clone/variety affect the quality of the final product? And how can such quality parameters as shape, colour, nutrient contents and taste be improved? The tubers' contents of substances affecting nutritional quality, such as inulin and other carbohydrates, will be analyzed. Knowledge about the different varieties' agronomic and quality traits is important for growers, but also for the processing industry. The project is therewith expected to provide important new know-how about Jerusalem artichoke varieties' potential for further breeding and selection.

Horseradish – Food, Magic & Medicine

Kerstin Olsson, Adviser, Svalöf Weibull AB, Sweden, kerstin.olsson@swseed.com
Katarina Wedelsbäck Bladh, Head of section, Nordic Gene Bank, katarina.wedelsback.bladh@nordgen.org

Horseradish (Armoracia rusticana) has longstanding traditions as a cultivated plant in the Nordic countries. The plant presumably originates in Turkey and south-eastern Europe, where it grows wild, but also has been cultivated for 2000 years. By the Middle Ages, horseradish was grown in central Europe, from where it was spread to the Nordic region by monks. Soon, the plant was also being grown outside of the monasteries, and became increasingly popular. In 19th century Sweden, large horseradish fields were established at Enköping, from where the roots were transported to the markets of Stockholm and other towns. Today, commercial horseradish cultivation is only being carried out at very few places throughout the Nordic region.

Horseradish has a characteristic, strong taste due to its content of glucosinolates, and has been put to a wide variety of uses. It was previously believed that the plant had magical powers. Rubbing your hands with horseradish was thought to prevent snakebites. The plant was also used to cure headaches, high blood pressure, gout, sciatica and digestive disorders. Seamen ate horseradish to prevent scurvy. Today we know that the last mentioned effect is due to its high vitamin C content. Horseradish was also used as a cosmetic. An ointment made from the plant could bleach the skin and give it a beautiful lustre. The plant also has a certain antibiotic effect, and was thus appreciated for more than just food purposes in the old days. Nowadays, horseradish is primarily used as a preservative and spice in cooking. However, recent research indicates that the plant in the future could be used to soothe certain types of chronic pain.

In cooperation with the Vegetable Working Group, the Nordic Gene Bank (NGB) has collected 150 horseradish clones from various parts of the Nordic region. These have later been cultivated in different Nordic clone archives. The morphological traits of the collected clones have been described, including the exterior of both tops and roots. The study shows that there are considerable differences between the appearances of the collected specimens.

In the Nordic countries, horseradish is mainly propagated vegetatively, since the species rarely produces seeds in our region. It was thus assumed that all horseradish populations throughout the Nordic region were more or less similar. To get a better understanding of the relatedness between the collected Nordic clones, an AFLP fingerprint analysis of the material was initiated. The analyses were conducted in NGB's laboratory. Results from the analysis of the Swedish clones show that the 70 analyzed horseradishes can be divided into nine different groups. The remaining Nordic horseradish samples will soon also be analyzed.

Important characteristics of horseradishes are their typical aroma and taste. All samples were thus analyzed for the contents of glucosinolates in the roots. The most dominant glucosinolate is sinigrin, which averages 82 % of the total glucosinolate content, and which is responsible for the horseradish's strong taste. Gluconasturtin accounts for 13 %, whereas other glucosinolates are only found in small amounts. However, the roots' chemical composition varies considerably. For example, the sinigrin contents in the Swedish samples varied between 13 and 39 µmol/g DM. This variation corresponded clearly with differences in the strength and character of the horseradishes' taste. Similar variations can be found in the other Nordic collections as well.

Another analyzed parameter was vitamin C contents in the roots, which also showed considerable variations (55-182 mg/100g).

Horseradish flower

PHOTO: KATARINA WEDELSBÄCK BLADH

Horseradish roots

PHOTO: KERSTIN OLSSON

The Icelandic Swede

Jónatan Hermannsson, Researcher, Agricultural University of Iceland, jonatan@lbhi.is
Sigríður Dalmannsdóttir, Researcher, Agricultural University of Iceland, sd@lbhi.is

The swede, also known as rutabaga, is a biennial crop belonging to the Cruciferae family. Swedes (Brassica napus) are a spontaneous cross between cabbage (Brassica oleracea) and turnips (Brassica campestris). The plant was initially bred in the early part of the 16th century, presumably, as suggested by its name, in Sweden. It was first mentioned in the literature in 1538. Swedes do not grow wild, but have been an important horticultural crop in the Nordic countries for the past centuries.

PHOTO: SIGRÍÐUR DALMANNSDÓTTIR

In Iceland, however, horticultural production was very limited for hundreds of years after the country's settlement. Old documents show that there were scattered gardening activities throughout the Middle Ages, especially in places where Danish officials lived. The use of household gardens first became widespread in the late 18th century. In the 19th century, the cultivation of garden crops became common among farmers.

Swedes were first mentioned in Icelandic documents in 1779. This is considered to be the earliest proof of the plant's existence in Iceland. Later, the plant was named 'gulrófa', which it has now been called for more than a century. In the mid 19th century, swedes were grown on nearly all Icelandic farms. However, towards the end of the century, the plant was grown to a much lesser extent due to years of cooler temperatures.

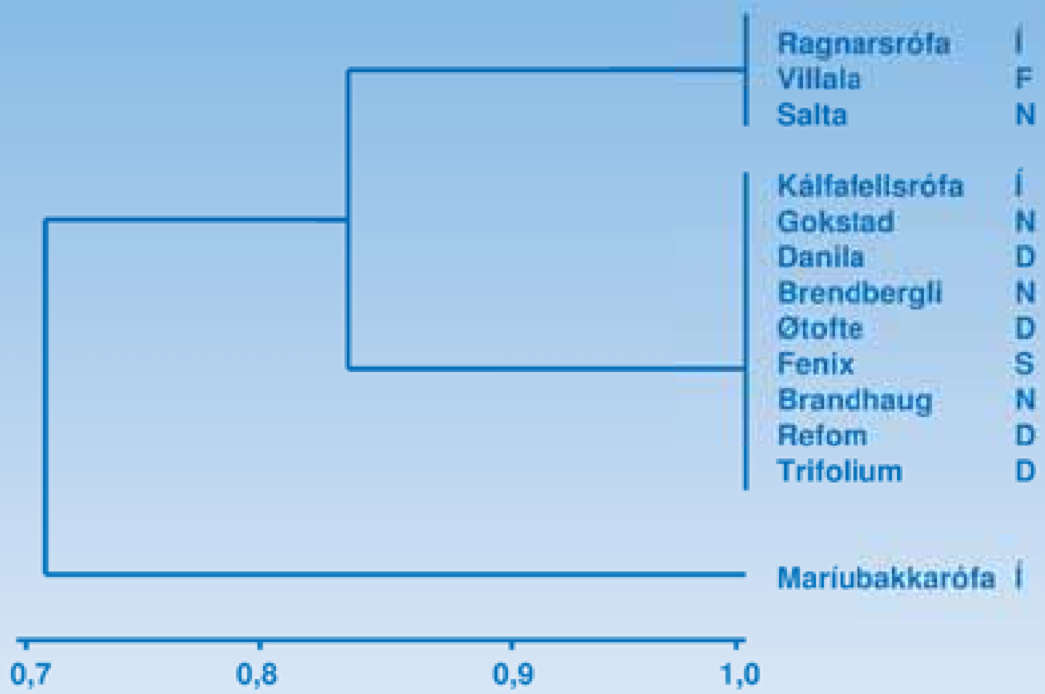
After this period of cooler weather, swede cultivation once again became popular in Iceland. Between 1890 and 1910, swede production averaged 18 kg per capita. This was followed by a rapid decline of production, especially after 1930, when the cabbage root fly came to Iceland. Today, the total swede production in Iceland amounts to about 1200 tons, grown on about 60 ha. This is equivalent to approximately 4 kg per capita.

In 1882, Georg Hans Schierbeck was appointed as head physician in Iceland. He was Danish, and had an unusual combination of professional training – as he was both a physician and a gardener. Dr. Schierbeck was determined to improve Icelandic horticulture. He initiated the first variety trials for swedes in the country and numerous Nordic swede varieties were tested under his supervision. He concluded that the Norwegian variety 'Trøndersk' was the most suitable variety for growing conditions in Iceland.

Georg Hans Schierbeck established the Horticultural Association of Iceland in 1885. The association's first task was to ensure a regular supply of a diversity of vegetable seeds. This included the cultivation of swede seeds. Dr. Schierbeck's swedes were grown as a separate variety, and became eventually known under the name 'íslenska gulrófan', the Icelandic swede. The variety was classified as a swede of Trøndersk origin, and was always easy to distinguish from other swede varieties. It was later approved as a local variety, and was the most popular swede in the country until 1950. The variety has a rather large root and large, upright leaves. The variety is now called 'Ragnarsrófa'.

The horticultural association was not only in charge of producing seeds in Iceland, but also for the import of seeds of foreign varieties that could be expected to thrive under Icelandic growing conditions. Around 1920, the Russian swede variety 'Krasnøje selskøje' was tested in the country for the first time. It is

A simple dendogram showing the relatedness between Nordic swede strains (Gert Poulsen 2000).



The Icelandic swede variety 'Ragnarsrófa' is related to the varieties in northern Norway. 'Kálfafellsrófa' has lost its uniqueness, and is now closely related to the southern Scandinavian varieties with which it has cross-pollinated. 'Maríubakkarófa', however, has a totally different DNA structure.

described as a small variety with a small, flat root. The swede was also known to be real delicacy. The horticultural association sent seeds of the Russian swede to many gardeners throughout Iceland, and documents show that the variety was extensively grown until the start of World War II.

Through the entire 19th, and far into the 20th century, most people grew their own swede seeds in their home gardens. This resulted in a number of local strains. In 1948, a survey of these local strains was carried out. The most promising of these was a strain that originated on a farm in south-eastern Iceland. It was later named after the farm, and was called 'Kálfafellsrófa'. It had small roots and drooping leaves.

The 'Kálfafellsrófa' was then widely grown for the next 30 years. However, homegrown seeds were no longer able to meet the demand. Swede seeds were thus grown in Denmark for several generations, although without any basic seed being kept. This resulted in considerable genetic contamination of the variety, especially from rape and wild turnip. The seeds were still sold in Iceland, but became increasingly less popular. For this reason, farmers began growing their own seed again, selecting their best swedes as mother plants.

In 1984, swede seeds from all over Iceland were once again collected. Studies showed that the dominating seed in this collection came from the 'Kálfafellsrófa' strain, which had been crossed with foreign cultivars. However, the original, pure strain of the 'Kálfafellsrófa' swede was also discovered on a farm near Kálfafell. This strain is now registered in the Nordic Gene Bank (NGB) under the name 'Maríubakkarófa'. All of the strains collected in 1984 were sent to the NGB, and are stored there as 'local material'.

In 2000, former NGB-employee Gert Poulsen performed a DNA fingerprint of 47 of the swede strains kept in the gene bank, 11 of which were from Iceland. The study showed that most of the Icelandic strains are not really unique, and are closely related to familiar foreign varieties. This also applied to the strain registered under the 'Kálfafellsrófa' name, whereas the 'Maríubakkarófa' swede, however, really was quite unique. This variety is not related to any other Nordic swede strain. If one groups the 47 studied strains of swedes according to genetic variation, two groups can be distinguished – one group consisting of only 'Maríubakkarófa', and the second group containing all the others.

The question thus remains: where does this completely unique 'Maríubakkarófa' swede come from? Perhaps the Icelandic fairies know the answer...

The EVA Inbreeding Management Programme

Morten Kargo Sørensen, Researcher, Danish Institute of Agricultural Sciences, morten.kargo@agrsci.dk
Anders Christian Sørensen, Researcher, Danish Institute of Agricultural Sciences, andersc.sorensen@agrsci.dk
Peer Berg, Research Director, Danish Institute of Agricultural Sciences, peer.berg@agrsci.dk

All those involved in animal breeding are familiar with the concept of inbreeding, and most are aware of the fact that inbreeding has unfavourable effects. The degree of inbreeding is the probability that both genes of a gene pair originate from the same ancestor in the animal's parentage. Inbreeding, which thus only can occur if both parents are related, has three unfavourable consequences: expression of hereditary defects, inbreeding depression and a reduction of genetic variation.

Inbreeding

Inbreeding is a problem in populations that are small in numbers, but it can also cause problems in large populations that are managed with a very limited number of sires. Thus, inbreeding presents a challenge both to small conservation populations and large, active commercial populations. However, there are ways to limit the negative effects of inbreeding. One of these methods is the Evolutionary Algorithm for Mate Selection (EVA). By accepting a slight reduction in genetic gain, the inbreeding rate can be considerably reduced. This means that the animals can avoid the unfortunate effects of an increasing rate of inbreeding. Based on the average relationship of the animals' and their breeding value, the programme can calculate the optimal genetic contribution from each animal, including the optimal number of progeny in the coming period. The EVA programme can also be used in small populations. However, in such populations, one totally neglects any focus on genetic gain, and exclusively emphasizes a reduction of the future inbreeding rate.

Long-term genetic gain

EVA can determine which breeding animals are to contribute to the next generation, as well as the number of progeny each of these should have. Furthermore, EVA can set up a mating plan to minimize the degree of inbreeding in the next generation, when the parents' optimal genetic contribution has been determined. Based on available data, the programme takes into consideration both previous parent combinations as well as the animals that are available as possible parents for the forthcoming progeny group. EVA is thus a dynamic tool, used to determine the combinations needed to optimize genetic gain while at the same time limiting the inbreeding rate. It can even be expected that a reduced inbreeding rate, and therewith a reduced decline of genetic variation, could contribute to increased genetic gain in following generations.

In addition to aiding in the selection of breeding animals and in the design of mating plans, EVA also includes a module for monitoring the degree of inbreeding in a population and for individual animals. Furthermore, the programme can calculate kinship between animals and individual animal's contribution to groups of animals.

Status quo

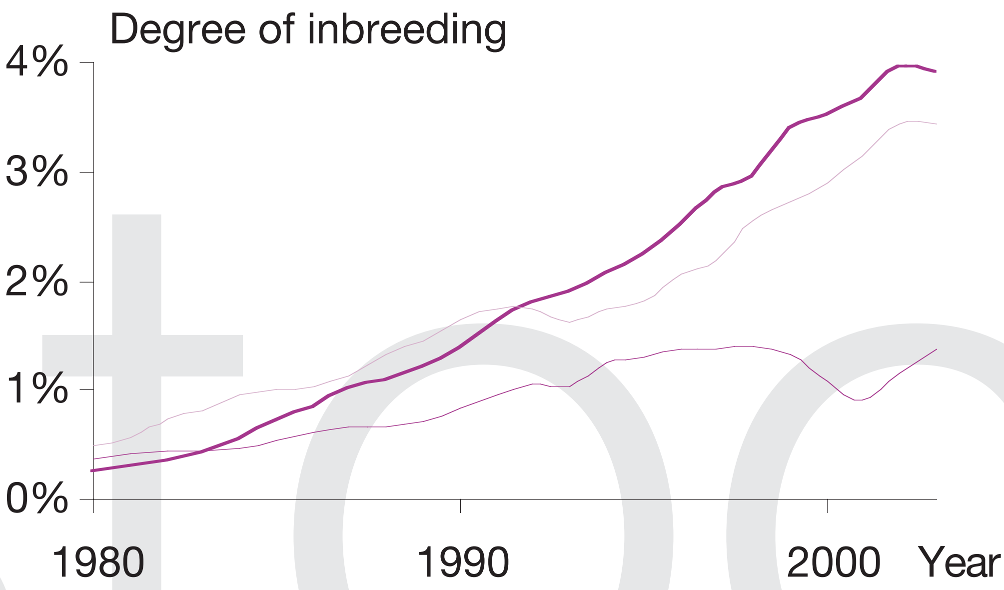
Livestock breeding has become highly efficient, and animals are constantly being improved in the short term, with regard to the traits they are being bred for. At the same time, this unavoidably leads to an increasing inbreeding rate, since an increasing share of the breeding animals are selected from the best families, which in turn results in the disadvantages mentioned above. Take for example the problem faced by the most commonly used dairy cattle breed in the western world, the Holstein Friesian (HF). Even in this dominating breed, the effective population size, a parameter for the degree of inbreeding, has declined drastically in the past few decades. Between 1960 and 1980, this value was around 200. From 1980 to 2000, the effective population size dwindled to 40. In 2003, 25 per cent of the genes of Danish Holstein bulls originated from merely two American ancestors. The same holds true for other HF populations as well. Studies of genetic profiles show that genetic variation is often at least of the same size in small, threatened breeds as in the large, commercial breeds. Methods for inbreeding management are therefore needed. At the herd level, an increase of the inbreeding rate can be avoided in the short term by controlling the mating of the parent generation.

Practical application

EVA is already being applied in commercial populations in the Nordic countries, especially within dairy cattle breeding in Denmark and Sweden. Courses on the use of the programme have been held, so far mainly for the coordinators of the breeding programmes within the

respective active populations. However, applications have been submitted for funds that would enable the training of coordinators of conservation breeding programmes.

The use of EVA, however, requires that the animals have been registered. Without pedigree information the programme cannot be used, since such information is necessary for determining the degree of inbreeding. Of course, animals can be inbred even if we have no access to their pedigree information, but in such cases, it is neither possible to compute their inbreeding coefficient, nor determine how to mate them appropriately in order to limit inbreeding. The more and better pedigree information is available, the better the programme can be utilized. Furthermore, if breeding values are available for the breeding goals in question, EVA can be used to optimize the balance between genetic gain and inbreeding rate.



During the past 25 years, inbreeding has increased dramatically, following the introduction of new methods for breeding value assessment and breeding plan design. The figure shows the development of the degree of inbreeding for selected Danish cattle breeds. Thick, heavy line - SDM, thin, weak line - Jersey, bottom line - RDM.

Farm Animal Genetic Diversity as a Resource

Erling Fimland, Director, Nordic Gene Bank Farm Animals, Norway, erling.fimland@nordgen.org

There is increasing interest for livestock and crop diversity as a "renewable resource" in the production of food and other agricultural commodities. The flexible supply of our most important consumer goods depends on securing the divisity of our genetic resources. Modern development trends, however, are generally a threat to diversity. In the long run, this will increase the risk of developing genetic systems that are poorly adapted to future production conditions. The accelerating rate of creating uniform, global markets also leads to the uniformization of primary production systems. In turn, this will eventually reduce the diversity of areas in which available genetic systems can be applied. The long-term effects of such a development may not only include the reduced utilization of marginal land, but also an increased risk of failure within existing production systems. With such a scenario in mind, there will be increasing interest for political processes based on the principles provided by the Convention on Biological Diversity and subsequent negoatiations – both nationally and internationally.

Current status

Numerous national laws and international guidelines (including EU directives) have previously been issued for the livestock sector, e.g., requirements to breeding programmes, procedures for artificial insemination, labelling animals and pedigree registration. However, none of the laws and regulations include provisions on the conservation of genetic diversity. The principles that focus on the value of biodiversity were politically negotiated in connection with the Rio Convention on Biological Diversity (CBD) in 1992, and further elaborated in Party Conferences, that so far have not yet been finalized. The CBD should be seen as an international law, to be implemented in nationally adapted legislature. Such national adaptation is underway in some Nordic countries, but not yet completed.

Internationally, national patent laws and the Convention on Biological Diversity are currently the formal regulations for farm animal genetic resources, as well as the general contract laws for buying and selling goods.

Norwegian dairy goat.

PHOTO: LIV LØNNE DILLE

What lies ahead for the farm animal sector?

Considering the international regulations that have been introduced for plant genetic resources in the past 20-30 years, it is likely that similar processes will be implemented by the parties to the CBD and under the auspices of the FAO. The Nordic countries and Europe should play active roles in this process to ensure the development of a system that is as simple as possible, and that avoids the most unfortunate effects of the exchange of genetic resources. An important milestone will be reached in 2007, when the FAO is to arrange a technical conference on farm animal genetic resources. It is expected that "regulations" will be discussed at the conference and important principles established.

The question that needs to be addressed throughout the negotiations prior to 2007, is whether or not an international treaty is necessary as a regulatory mechanism, or if simpler forms of genetic exchange can secure the access to and fair sharing of benefits and values between parties, given that requirements for sustainable utilization and sufficient conservation of genetic variation are realized.

Nevertheless, the national responsibility for maintaining farm animal genetic resources is the main issue. This is clearly expressed by Swedens Minister of Agriculture and Consumer Affairs, Ann-Christin Nykvist: "By protecting the animals' unique traits, we are taking responsibility for securing the food supply for future generations. We stand stronger when it comes to dealing with future challenges such as environmental changes, diseases and famine. Reducing the genetic diversity of our farm animals, however, leaves us more vulnerable and undermines the basis of social and economic welfare".

PHOTO: ASLAK SNARTEDAL

New Paths for an Old Breed

Karl N. Kerner, Translator & Freelance writer, Norway, karl@agroling.no
Hilde Dolva, Freelance writer, Norway, hilde@agroling.no

This year, the Telemark cow is celebrating its 150th anniversary, and is thus Norway's oldest native cattle breed. Recently established businesses based on innovative utilization of Telemark cattle prove that old breeds can be used for much more than grazing at museums.

Innovation in a historical environment

Nine farmers in western Telemark have established a dairy company for processing milk from about 60 Telemark cows in the region. This may seem like a modest number, however, the cows represent about 20 % of Norway's registered Telemark population. Operations are planned to begin in June 2006.

One of the farms is the Snarteland farm in the municipality of Fyresdal. The picturesque farm lies on the edge of an alluvial deposit, with steep hillsides right behind the barn. When Aslak Snarteland inherited the farm in the early 1990s, there had not been cattle in the barn for more than 30 years. However, Aslak says he has always had an interest in cattle and farming traditions. He was awarded an extraordinary milk quota based on a comprehensive assessment of the farm's location, its buildings and the use of old livestock breeds. Aslak and his neighbour have established a joint operation, and now have a herd of 30 dairy cows, of which 20 are purebred Telemark.

A breed is born

A mere 60 km from the Snarteland farm lies the village of Kviteseid, where the Telemark breed was formally established on 19 September 1856. Founding cattle breeds was not a unique Norwegian phenomenon, but rather part of an international trend at the time. For example, Angus was established in 1836, Hereford in 1846 and Charolais in 1864.

Furthermore, the establishment of breeds and the beginning of systematic livestock breeding can be seen as part of the national awakening that took place throughout Europe in the mid-1800s. Those were the days when Asbjørnsen & Moe published their first collections of fairy tales and Bjørnstjerne Bjørnson wrote Norway's national anthem. The only thing lacking was a national cattle breed. At the time, the state agronomist Johan Lindeqvist had been conducting his own studies, and in his opinion, the Telemark cattle were especially suitable for further breeding.

Old cows in a new niche

To begin with, the newly established Telemark dairy plans to produce butter, sour cream and a local, traditional sour-curd cheese. The dairy's location in the heart of rural Telemark is definitely an asset when it comes to brand building, but the same remoteness is also a drawback, as it is a long way from most potential markets. The cooperating farmers have already established contacts with other niche producers and tourist establishments in the area, and plan on developing a joint-distribution system.

If processing products from old livestock breeds is to become a viable alternative, it has to be profitable in the long run. A Telemark cow gives about 3500 l of milk per year, approximately half of the yield of a Norwegian Red, the dominating commercial dairy breed in Norway. In addition, Telemark cows often do not peak until their third or fourth lactation. Why would anyone thus choose to put their stakes on this breed? And how is it possible to achieve a reasonable financial outcome? Aslak explains: "Keeping these animals becomes quite a passion. Telemark cows really have a personality! But having said this, we obviously can't cover all of our extra costs via market prices. Preserving our genetic diversity is an official policy and thus a public responsibility. But we've been really lucky – both local and regional authorities provided professional and financial support along the way, and a regional research institute really helped us in the initial phases. Also, all farmers in Norway keeping old breeds receive an annual subsidy of NOK 900 per animal, while the county of Telemark pays another NOK 1200 per animal."

How do you define a Telemark cow?

The Telemark dairy initiative is one of the first cases in Norway of business development based on utilizing a specific animal breed. Getting a head start can be an advantage, but also means facing new challenges.

For example, how much infusion of other breeds can be tolerated in products marketed under a ”Telemark” label? Aslak explains that to begin with, farms wishing to be included in the Telemark marketing scheme must document a minimum of 50 per cent Telemark lineage in individual animals and at least 7/8 at the herd level. The Telemark farmers are also developing additional guidelines, such as minimum grazing periods and preferably the practice of summer mountain dairying. Both of these aspects underline the importance of Telemark cattle for the landscape – or was it vice versa?

Avant-garde cowhides

Consumers are increasingly demanding local food and other products with special qualities. This trend provides new possibilities for utilizing old livestock breeds – especially for creative minds! For example, in connection with the newly established dairy in Telemark, there are also plans to establish a meat-processing plant, which will specialize on utilizing local ingredients, such as meat from sheep, deer, elks – and Telemark cattle.

However, cows provide other raw materials than milk and meat. Bine Melby in Kongsvinger is treading a totally new path: she uses hides and horns from Telemark cattle to produce clothes, jewellery and table runners. Bine hopes to present a collection of clothes made from Telemark cowhide at this year’s livestock show in Seljord to celebrate the breed’s 150th anniversary. Her products receive additional attention due to her use of hides from old, native breeds. She explains this choice: “I’ve been professionally involved in the conservation of old breeds for quite a while, and I wanted to actively contribute to the utilization of these resources. Most of the clothes I make are based on haired hides, and thus, the Telemark hides are an obvious choice with their wonderful colour markings. My goal is to focus on excellent craftsmanship and at the same time tell the story of a threatened cattle breed.”

PHOTO: ASLAK SNARTEDAL

PHOTO: MONA NORDØY © BINE MELBY

PHOTO: LIV LØNNE DILLE

Better products or an interesting story?

When marketing products from old cattle breeds, an obvious question is: are these products different, or perhaps even better than those from modern, high-yielding breeds? So far, there seems to be more speculation than scientific data on this issue. For example, it has been mentioned that milk from old breeds may have a different protein composition, and thus perhaps better cheese-making properties than milk from modern breeds. Likewise, some scientists assume that muscle fibre composition may be different in the old breeds. In any case, there is obviously a need for more research in this field.

Is it thus mainly the story about Telemark cows that is being sold? “Yes, absolutely” says Aslak, but quickly adds that this story is an important one: “Take a look at the Telemark, she’s a lightweight cow with wonderful markings and elegant horns. Actually, she’s a lot like the people of Telemark: good-looking and well-adapted to the rough terrain, but she’s also somewhat stubborn and can occasionally be hot-tempered. The Telemark cow really has distinctive characteristics, and we have to preserve those!”

It is easy to understand Aslak at the sight of grazing Telemark cows, which seem to be predestined for the hilly terrain. No economic analysis will be able to capture the entire picture – these cows are so much more than merely milk producers. They represent a much broader scope of values – values we must not lose, namely local traditions, culture and identity.

PHOTO: CAMILLA ELOFSSON

The Linderöd Pig

Camilla Elofsson, Gene Bank Coordinator, Swedish Landrace Pig Association, camilla.elofsson@tele2.se

History
There used to be two distinct types of landrace pigs in Sweden. One was the forest (or 'acorn') pig, the other the domestic pig. The forest pig was mainly found in the wooded areas of southern Sweden, where some crossbreeding with wild boars surely occurred throughout the centuries. The Linderöd pig bears a closer resemblance to the domestic pig, but has the colour variations of the forest pig. Early protection of the Linderöd pig already began in 1952 when the Skåne Zoo was established in Höör. Today we can confirm that the landrace has a surprisingly stable genotype. Absolutely no all-white animals are born, thus indicating that we really are dealing with an old landrace breed, maybe even more native and with less infusion from imported breeds than assumed to begin with. In 1999, the Linderöd pig was approved to be eligible for EU and Swedish environmental support for threatened livestock breeds – as the only Swedish landrace pig.

Breed description
The Linderöd pig is a medium-sized landrace pig. Its legs are strong and muscular, its body form slightly round. Its body is somewhat shorter than in modern breeds, although some animals of the so-called Halland line can have longer bodies than animals of the so-called Skåne line. The pigs are black-mottled on a white/grey or brown base colour. White animals often have large black spots, whereas brown animals usually have many small spots. Sometimes the black spots can be large enough to make the animal appear nearly black. Mottling can vary considerably, and some animals are predominantly white or almost completely brown. Brown pigs are orange-coloured when young, and gradually turn brown or grey as they get older. A roan base sometimes occurs, giving the animals a yellowish appearance. Colour plays no role when selecting breeding animals.

The ears can vary somewhat in size. Usually they are medium-sized, erect and point slightly forwards, almost like sun protectors. Long, lopping ears were never a breeding goal, since drooping ears easily get wet in drinkers and freeze in winter. The snout is straight and well-formed – and is neither pointed like the wild boar's, upturned like the Yorkshire's nor blunt like the snouts of many Asian breeds.

PHOTO: CAMILLA ELOFSSON

Grazing
The Linderöd pig is well adapted to the climatic conditions in Sweden. It is therefore best suited for year-round outdoor grazing. Even when farrowing, the Linderöd should be outdoors. If, for any reason, sows must be kept indoors during farrowing, they should have plenty of space and access to nesting material. Otherwise, a solid hut with one open side and a dry earth floor is the best type of housing. In winter, pigs need straw for insulation and, above all, sufficient amounts of feed. In summertime, they appreciate a cool mud pool.

Population
Today, the Linderöd pig population counts 81 boars and 200 sows, distributed among 105 conservation herds all over Sweden. A gene bank 'conservation ark' is a member of the Landrace Pig Association and has signed a gene bank contract with the association.

Breeding work
To ensure the success of our breeding efforts, we are using a closed herdbook. This implies that only animals with sufficient pedigree information can be used for breeding purposes. All conservation herds have the right to issue a gene bank certificate for Linderöd pigs they sell. The certificate gives the animal's owner the right to enter the animal in the herdbook, and thus also become a gene bank. The gene bank coordinator is responsible for managing the herdbook, recommending animals for breeding, and making sure that we do not lose important breeding stock.

The most important goal is to maintain diversity. By ensuring that all conservation herds sell their animals to other, already existing or new conservation herds, the distribution of breeding stock is maximized. The Landrace Pig Association does not have access to semen, so farmers must have their own boar, borrow a boar or transport their sows to a boar. Thus, one also maintains a larger breeding population.

Forest Seed Orchards and Gene Diversity

Dag Lindgren, Professor, Swedish University of Agricultural Sciences, dag.lindgren@genfys.slu.se

Diversity has advantages

There are arguments that genetic diversity may improve the volume production of a forest. Similar trees require the same inputs at the same time, while a diverse crop ought to utilize the production capacity of the site better. Low diversity is often associated with high inbreeding, which is negative for production. A disease or pest is expected to spread faster in a uniform crop than in a diverse stand. In cases in which a uniform plantation fails, successful individuals in a diverse crop may take over and save the stand, thus a uniform crop is likely to fail more often than a diverse one. If trees are different, the stand can be improved by artificial or natural selection. If seed orchard clones are different, the seed orchard may be modified after establishment by thinning or selective harvesting. Diversity creates options and flexibility.

Diversity is politically correct and has a high PR-value. Diversity facilitates eco-certification. Appearing environmentally friendly contributes to immediate sales and boosted profits. A non-uniform forest may provide advantages to other beings.

Crop production is, however, a matter of economy, not biomass production. A uniform crop is easier to manage, both in the forest and in the nursery. Uniformity is preferred by industry; and uniformity is better paid. The possible production advantages of diversity may be quantitatively small, and the economic advantages of uniformity can appear larger in some production systems.

Seed orchard crops are diverse

The seed orchard crops harvested today can be considered as genetically diverse, in spite of that the plus trees were selected for seed orchards according to stringent and uniform standards. Although a gain was achieved, the genetic variation remains, as the appearance of the selected trees did not reflect their genes well. Not much was gained by selecting a small number of plus trees for use in seed orchards, the average number of clones in typical Scandinavian seed orchards of pine and spruce is in the hundreds. The expected variance of a sample larger than about 10 is almost as large as the variance of the sampled population, indicating that the number of clones in a seed orchard is not critical. The parents of a natural forest tend to be related and share a recent history, but the parents of a seed orchard are recruited from a region spanning hundreds of kilometres under variable conditions, and thus less related and more diverse.

New seed orchards will contain trees selected on the basis of their ability to produce good progeny instead of their appearance in the forest. Even in this case there are factors conserving diversity. The estimates of breeding values are not accurate, mainly because the estimates are based on experience from a limited part of the rotation period. Clones will be selected on the basis of an index weighting different traits, which means that the individual traits will be variable even if the variation of the selection index itself narrows down. Clones selected on the basis of information from different trials under different conditions will be brought together. There are thousands of active genes and the selection will only affect a very small percentage of them.

All genes from a forest planted with seed orchard material do not originate from the seed orchard parents. Naturally regenerated trees will give a significant contribution to the resulting stand, perhaps about 20 %. Pollen inflow in seed orchards is likely to comprise 50 % of fathers. Thus, selected trees often only contribute somewhat more than half of the genes in forests originating from seed orchard material. Forty percent of the produced forest seedlings in Sweden are from stands. Natural regeneration is applied on 37 % of the forest area in Sweden. Many forest trees grow on areas that are not classified as forest land and seldom planted. Even if the use of seed orchards will make a difference, the impact will be felt slowly over time. The average age of a tree cut in Sweden is more than a hundred years, while seed orchard crops have become common only for the last couple of decades.

A mature Scots pine seed orchard close to Umeå in northern Sweden. PHOTO: DAG LINDGREN

Rare gene variants may be important for evolution, but not for the production of an individual stand. Their survival chances are good, considering that millions of trees will transmit their genes to coming generations in the future.

Higher levels of genetic diversity than the within-species diversity at the stand level seem to be of considerably larger biological significance than diversity of seed orchards for most purposes. Thus, the issue of seed orchard diversity may be a rather marginal one.

Quantifying diversity

The new seed orchards established today typically use tested clones with known breeding values. This creates a situation with the evident, large and quantifiable advantage of having few clones in seed orchards. The fewer clones that are selected on the basis of their breeding value from a limited number of tested clones, the higher the genetic gain will become. Thus, a quantitative trade-off with the disadvantages of a low clone number is desirable.

Quantifying an assumed disadvantage of the possible negative impact on gene diversity from seed orchards of the planted forest, including risks of failures, is hampered by the lack of results from relevant experiments. One example is mentioned in the following.

In south-eastern USA, most planted pine stands originate from a cone harvest of a single mother clone. The trees in the stands are half sibs. Experience does not indicate any negative consequences of this low diversity. The southern pines in the USA can be considered as one of the most successful forest plantation programs in the world. The absence of observations of a negative impact of a low diversity in cases like this makes it possible to deduct a higher bound for the possible negative effects of a low diversity.

The magnitude of the possible negative impact on production from lack of diversity is unlikely to be more than a few percent of the forest production for a typical new Swedish conifer seed orchard with around 20 clones. The predicted genetic gain is in the order of 20 %, much larger than the possible disadvantage.

trees

Vegetative Propagation and Cryopreservation of Forest Trees for Use and Conservation of Genetic Resources

Tuija Aronen, Senior Researcher, Finnish Forest Research Institute, Punkaharju Research Unit, tuija.aronen@metla.fi

Using vegetative propagation to clone the best trees

Vegetative propagation, or cloning, of forest trees is an alternative to the use of seeds in the production of forest stock. When trees with a high growth rate or good wood quality are propagated vegetatively, their beneficial genetic makeup can be completely utilized – which is not the case when using seed propagation. Thus, one can quickly utilize the best trees to produce forest trees with a uniform quality. The trees' unique and specific characteristics can therewith be utilized. On the other hand, the genetic diversity of the forest stock decreases with decreasing numbers of utilized clones. Even if vegetative propagation is not directly used in forest regeneration, the efficiency of forest tree breeding can be improved by using clonal plants instead of seedlings to test breeding material.

Vegetative propagation methods used to produce forest regeneration material include propagation by cuttings and tissue culture. Cuttings can be made from both roots and shoots. The most common tissue culture methods are micropropagation based on organogenesis and somatic embryogenesis, i.e., production of somatic embryos. Compared to seed propagation, micropropagation requires a considerable input of manual labour and special facilities, which is why cloned plants are more expensive than seedlings. All tree species and propagation methods have one thing in common: there are always certain trees that seem to be difficult to clone. This must be taken into consideration when selecting trees to be used in the production of forest stock.

Propagating Nordic forest trees from cuttings

Vegetative propagation from cuttings is best suited for aspen, hybrid aspen, spruce, poplar and willows. Propagation from cuttings is easiest to perform on young plants (2 years), or for spruce, on plants kept young through pruning. Depending on tree species or within-species variations, a maximum of 300 cuttings can be produced from a single plant in the course of three years. The price of plants from cuttings is about 1.5-2 times the price of seedlings.

To propagate aspen and hybrid aspen, root cuttings are used, i.e., pieces of roots that are left to first form shoots and then a proper root system. Practically all forest stock comes from tested clones, either as cuttings or micropropagated plants. However, the area on which these species are grown is not large. In Finland and Estonia, for example, cloned aspen was planted on only about 100-200 ha each year since the late 20th century. However, there is growing interest in energy crops and short-rotation forests. This may lead to increased cultivation of fast-growing trees like aspen, hybrid aspen and willows.

Spruce can rather easily be propagated by rooting shoot cuttings from young plants. A practical example is the clonal forest project in central Sweden, a joint project conducted by the Forestry Research Institute of Sweden (Skogforsk) and Swedish forest companies between 1989 and 2001. The project tested 5000 spruce clones, and about one million cuttings were produced for forest regeneration. Results showed that the best 10 % of the clonal cuttings had a 39% higher height increment than seedlings commonly used in area. The vegetatively produced plants also had less insect damage. However, in order to cut costs it was considered necessary to either bulk-propagate cuttings – i.e., use the offspring of the best trees to produce cuttings, without testing each cutting clone separately – or utilize tissue culture.

Tissue culture is more efficient than propagation from cuttings

When using tissue culture in the micropropagation of hardwoods, one usually initiates cultures from vegetative buds, which also may originate in an old tree. The buds are induced to produce small shoots, whose growth and multiplication is regulated by the contents of growth hormones in the nutrient medium. These shoots are eventually rooted. This method is more efficient than when using cuttings – in one year, as many as 10,000 plants can be produced from a single tree.

In Finland in the early 1990s, about one million micropropagated silver birch (B. pendula) plants were

PHOTO: TUIJA ARONEN

Tissue culture of hardwoods is usually initiated from vegetative buds.

PHOTO: JOUKO LEHTO

Birch shoots produced from cryopreserved buds.

PHOTO: LEENA RYYNÄNEN

Somatic embryos in a pine tissue culture.

PHOTO: TUIJA

Pine plants propagated by tissue culture have been moved to a greenhouse.

produced for use in forestry. However, operations were phased out due to dwindling demand and the poor economic situation. Currently, birch is being cloned for research purposes, for growing specific forms and for the production of curly birch. Also, the specific forms of many other hardwood species are commercially propagated using tissue culture. Such trees are widely used as ornamental trees or in landscaping.

Tissue culture of conifers is based on the production of somatic embryos. For our native species, spruce and pine, this has only succeeded from very young plant material, the seed embryo. In tissue culture, the entire embryos are produced and then germinated. The production capacity is tremendous: within one to two years, one million ‘offspring’ can be produced from a single plant. The production of somatic embryos is easier to automate than the use of micropropagation. For mass-production, it should be possible to grow the embryos in bioreactors, and the produced embryos could be encapsulated and used as ’artificial seeds’. Many biotech companies are interested in the production of somatic embryos from conifers, and many of the various steps of the production method have been patented. When tissue culture propagation involves manual labour, the price of plants is 2-5 times higher than the price of seedlings, depending on tree species and propagation method. However, with the introduction of automated production systems, such plants will become cheaper.

The production of somatic embryos from spruce seed embryos has been mastered at a small scale. According to the results of the Swedish study, this method enables the production of plants from all spruce families, even if only about one-third of the individuals actually can be propagated. In practical terms, we still have no experience from the tissue culture of spruce plants for use in commercial forestry. Presumably, it will take another ten years before the propagation methods are mature enough for large-scale use at competitive prices. Within this period, spruce clones propagated by tissue culture shall be tested in Swedish field trials. Clone tests are needed since tissue culture is based on the use of seed embryos, and therewith the properties of the cloned plants are unknown. Vegetative propagation of pine is difficult, and the methods developed for cutting propagation and tissue culture so far will not be practically applicable in the near future. The main challenge regarding tissue culture is that only a small percentage of pine trees can be propagated in this way, and also, the somatic embryos germinate poorly.

Cryopreservation of genetic material

Cryopreservation, i.e., the storage of plant material at extremely low temperatures, is applied together with tissue culture. Samples, either as hardwood twigs with buds or coniferous tissue cultures, are submerged in liquid nitrogen (-196°C), where they theoretically can be stored indefinitely without changing. Thawed samples are then used to produce plants with an appropriate tissue culture method. Deep-freezing plays a specifically important role in the production of somatic embryos from conifers, since without cryopreservation, cultures age and lose their embryogenic capacity while the plants produced from them are being field-tested. When the best clones have been selected in field trials, the frozen samples of the corresponding cultures are then thawed and mass-propagated.

Cryopreservation is also a way to generally conserve forest tree genetic resources, as long as there are suitable tissue culture methods for the species in question. A container of liquid nitrogen represents a gene bank in which hundreds or thousands of specimens can be stored in a very small space and with minimum maintenance. The trees thus stored are also protected from external threats such as diseases, pests and uprooting, e.g., due to construction. Cryopreservation can also be used to preserve specific tree forms, valuable specimens or species at risk. Frozen samples can also function as a backup for existing clonal plantations. Cryopreservation methods are available for all of our main tree species, i.e., pine, spruce, birch and aspen.

Wild Apple Trees in Europe

Anders Søndergaard Larsen, Research assistent, Forest & Landscape Denmark, ansl@kvl.dk

It is generally known that we currently risk losing many of the thousands of apple varieties existing world-wide, due to such developments as rationalization and intensification of commercial fruit production. To counteract this trend, the Nordic Gene Bank has established clone archives of our national varieties for breeding and conservation purposes, or for use as a variety pool for interested growers. However, while lots of efforts have been made to conserve and describe varieties of the domestic apple (Malus x domestica Borkh.), the European wild, or crab, apple (Malus sylvestris (L.) Mill.) has often been ignored. The crab apple is widely found throughout most of Europe and the southern parts of the Nordic region. The species occurs as a natural element in open landscapes or in recent forest and thicket regrowth.

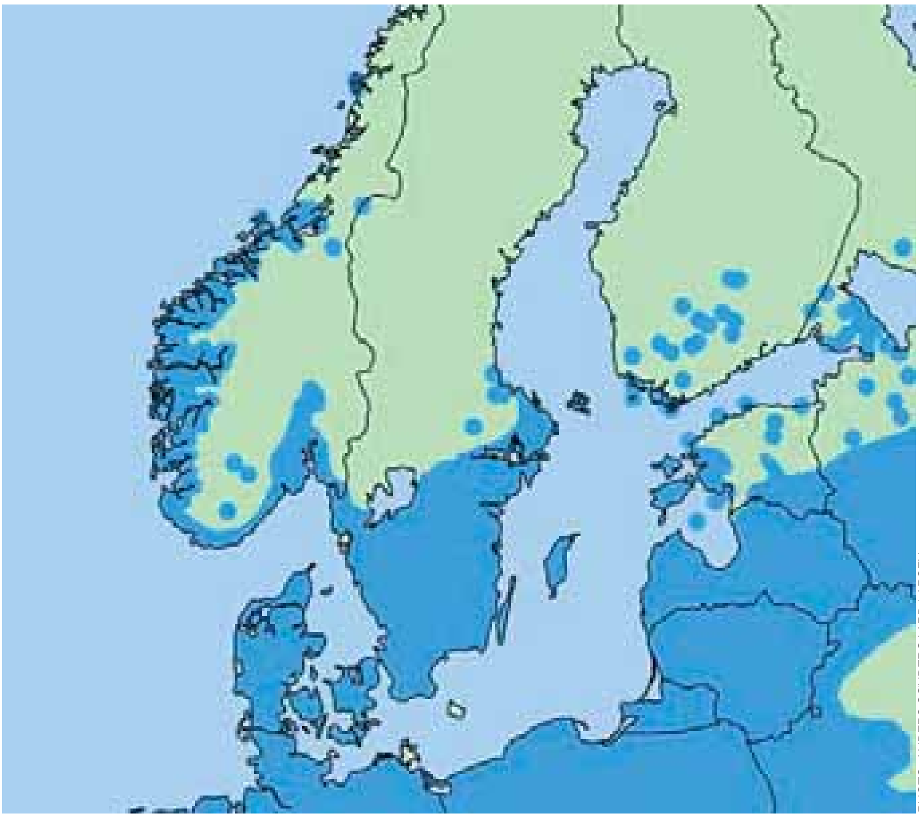


PHOTO: ANDERS SØNDERGAARD LARSEN

Geographic range of the crab apple (Malus sylvestris (L.) Mill.) in the Nordic countries.

Wild vs. cultivated genes

For a long time, the crab apple was regarded as the ancestor of the domestic apple. However, modern genetic studies indicate that the crab apple only had a minimal influence on the development of the domestic apple. Instead, the origins of the domestic apple can seemingly be traced to the Caucasus, where it is assumed that the fruit's domestic form arose several thousand years ago, as the result of the local population's domestication of indigenous apple species. Throughout Europe, however, morphologically intermediate forms between domestic and crab apples can be found. This has given rise to substantial concern regarding to what degree genetically pure crab apple populations can be found in our modern landscapes. It is generally known that plants within the genus Malus have a considerable ability to cross-pollinate between different species. In connection with the national programme for the conservation of genetic resources of Danish trees and shrubs, a study was therefore initiated to focus on the migration of genes from domestic apples to wild crab apple populations.

Status and future management

The study of hybridization between the two species was performed on about 180 individual trees from four Danish crab apple populations, which had varying population sizes and varying degrees of isolation from present occurrences of domestic apple trees. The study was performed using a specific type of genetic markers called microsatellites, with which it is possible to make genetic fingerprints of the examined individuals. Based on the fingerprints and the use of statistical analysis it is possible to estimate the degree of relatedness between the individuals – and thus also between the two studied species. Analyzing the results, it was remarkable that the two species formed two separate groups, and that additionally only four individuals were found that could be distinguished as first-generation hybrids, i.e., crosses between a crab apple and a domestic apple. These crosses were found in the two populations that were considered to be the least isolated from domestic apples, based on an assessment of local and regional occurrences of the domestic species. The results show that, in spite of the two species having co-existed in Denmark since the Middle Ages, it is still possible to localize crab apple populations that have maintained their genetic integrity to a considerable extent.

For a closer study of the factors preventing the hybridization of the two species, numerous additional analyses were performed. As expected, a pollination experiment showed that the two species are apparently totally compatible. However, in order for two species to crossbreed under natural conditions, the genes must not only be physically transferred from one individual to another, but this must also occur at exactly the right time. A study of the flowering dates of the two species showed that crab apples flowered two weeks earlier than their domestic relatives. Thus, even though the two species' flowering periods overlapped, their flowering peaks did not coincide. Furthermore, a marker-based "paternity analysis" among the offspring of one of the four populations showed that pollen was only dispersed across relatively short distances – on average about 65 metres. However, half of all observed pollen dispersals covered less than 30 metres.

Even though the species' flowering phenology seemingly has prevented widespread hybridization within the studied populations to a considerable degree, the occurrence of morphologically intermediate individuals nevertheless shows that cross-pollination has taken place. In an intensively cultivated country like Denmark, one would hardly expect to find populations that are completely unaffected by hybridization. Nevertheless, the results are important for the Danish conservation efforts, since they enable us to identify "authentic" crab apple populations, and also can be used to design and manage seed sources for future forest and landscape plantations.

PHOTO: ANDERS SØNDERGAARD LARSEN

Crab apple tree on a heathland pasture.

Crab apple tree on an extensively grazed area.

PHOTO: ANDERS SØNDERGAARD LARSEN

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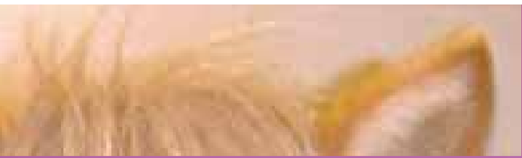
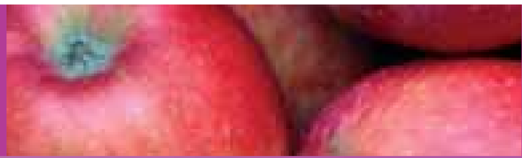
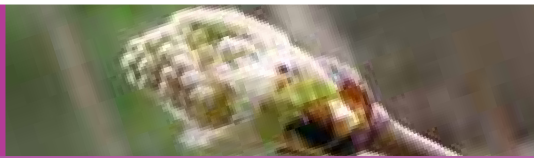

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Nordiska Genbanken (NGB)
P.O. Box 41, SE-230 53 Alnarp
Phone: +46 40 53 66 40 • Fax: +46 40 53 66 50
E-mail: ngb@nordgen.org • Web: www.nordgen.org/ngb

Nordisk Genbank Husdyr (NGH)
P.O. Box 5025, N-1432 Ås
Phone: +47 64 96 51 64 • Fax: +47 64 96 51 01
E-mail: ngh@nordgen.org • Web: www.nordgen.org/ngh

Nordiska skogsbrukets frö- och planträd (NSFP)
v/ Lennart Ackzell, National Board of Forestry, SE-551 83 Jönköping
Phone: +46 36 15 57 05 Fax: +46 36 16 61 70
E-mail: nsfp@nordgen.org • Web: www.nordgen.org/nsfp

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