NIBIO
NORWEGIAN INSTITUTE OF
BIOECONOMY RESEARCH

Introduction of new fruit crops to Norway

NIBIO REPORT | VOL. 9 | NO. 32 | 2023

Darius Kviklys, Oddmund Frøynes and Mekjell Meland
Division of Food and Society, Department of Horticulture/NIBIO Ullensvang

TITTEL/TITLE
Introduction of new fruit crops to Norway

FORFATTER(E)/AUTHOR(S)
Darius Kviklys, Oddmund Frøynes and Mekjell Meland

DATO/DATE:	RAPPORT NR./ REPORT NO.:	TILGJENGELIGHET/AVAILABILITY:	PROSJEKTNR./PROJECT NO.:	SAKSNR./ARCHIVE NO.:
01.03.2023	9/32/2023	Open	52693	21/01356

ISBN:	ISSN:	ANTALL SIDER/ NO. OF PAGES:	ANTALL VEDLEGG/ NO. OF APPENDICES:
978-82-17-03248-9	2464-1162	34	

OPPDRAGSGIVER/EMPLOYER:	KONTAKTPERSON/CONTACT PERSON:
The Norwegian Agriculture Agency	

STIKKOD/KEYWORDS:	FAGOMRÅDE/FIELD OF WORK:
Climate change, cultivars, peach, nectarine, apricot, grape	Horticulture

SAMMENDRAG/SUMMARY:

Klimaendringar gjer at nye vekstslag som vert dyrka lenger sør i Europa, og krev høgare veksttemperatur, kan verta introduserte og dyrka kommersielt i dei klimatisk beste fruktdyrkingsområda i Noreg. Dette vil auka biodiversiteten i hagebruksproduksjonen og gjeva fleire vekstslag å velja i for fruktdyrkarane. Fram til no er det avgrensa røynsle med å dyrka meir varmekrevjande fruktarter i Noreg. Føremålet med dette prosjektet var å sjå på vilkåra for å introdusera dei nye fruktartene druer (bord/vin), fersken, aprikos og nektariner. Prosjektarbeidet er tufta på litteraturanalysar, spørjeundersøking hjå dyrkarar og forskarar og informasjon frå vitjingar til dyrkarar og forskingsinstitutt i Noreg, Sverige, Latvia og Litauen. På grunnlag av desse kjeldene kan ein slå fast at vindruer og aprikoser kan dyrkast i området med det beste lokalklimaet i Noreg. Men borddruer, fersken og nektariner er meir kravfulle å dyrka. Aktuelle sortar av desse artene er vurderte som egna til kommersiell dyrking eller utvida prøving i sortsforsøk.

Global warming benefits enrichment of the assortment of cultivated fruit trees. New fruit species, less winter hardy, demanding higher temperatures during their growth and longer vegetation period, could become new commercial crops in Norwegian orchards. Up to now there is a lack of knowledge and experience with new fruit species in Norway. Main goal of the project was to justify the possibilities of introduction of new fruit crops namely table/wine grapes, peaches, apricots, and nectarines. The project implementation was based on literature analysis, questionnaires of growers and scientists, information gathered during the visits to scientific institutions and farmers in Norway, Sweden, Latvia, and Lithuania. According to growers' experience and research performed in

Norway, neighbouring countries and in regions with similar climate, a number of wine grape and apricot cultivars can be successfully grown in Norway. However, table grapes, peach and especially nectarine are more risky crops. After comprehensive analysis of cultivar characteristics and management, recommendations for the introduction of new cultivars were prepared for commercial growing or additional cultivar evaluation trials.

LAND/COUNTRY:	Norway
FYLKE/COUNTY:	Vestland
KOMMUNE/MUNICIPALITY:	Ullensvang
STED/LOKALITET:	Lofthus

GODKJENT /APPROVED	**PROSJEKTLEDER /PROJECT LEADER**
Inger Martinussen	Mekjell Meland
NAVN/NAME	**NAVN/NAME**

Preface

Due to short and relatively cool growing season in Norway, the commercial fruit production is limited to grow the fruit species apple, pear, European plum and sweet cherry. For sweet cherry, the same cultivars as in the rest of the world can be grown, developing large yields of good quality. However, for the three other crops and especially apple and pear only early season cultivars in countries further south can be managed properly and give good quality fruits.

Climate change giving higher temperatures and longer growing seasons have some positive sides from the agronomic view. New crops can be cultivated and improvements of the production of the current crops and thus increased biodiversity. In Norway, currently the crops apricot, peach, nectarin and table and wine grapes are grown in small gardens having favorable climate in Southern Norway. In addition, some fruit farms have started a small-scale production of apricots and grapes for wine.

Main goal of this project was to justify the possibilities of introduction of the new fruit crops table/wine grapes, peaches, apricots, and nectarines. The project implementation was based on literature analysis, questionnaires of growers and scientists, information gathered during the visits to scientific institutions and farmers in Norway, Sweden, Latvia, and Lithuania. Recommendations are given for the introduction of new cultivars for commercial growing or additional cultivar evaluation trials.

The project was funded by the Norwegian Agriculture Agency.

Lofthus, 01.03.23

Mekjell Meland

Project leader

Content

1 Introduction

Growing of fruit crops customed to Southern countries is moving to the northern borders and with predicted 2 degrees increase of the average temperature, the climate in Norway could be compared what is in northern Germany now (https://www.regjeringen.no). Across Norway, the agricultural growing season could become up to two months longer due to climate change. This creates new opportunities for the farmers. New fruit species, less winter hardy, demanding higher temperatures during their growth and longer vegetation period, cultivated now mostly at amateur level, could become new commercial crops thus increasing biodiversity in Norwegian orchards.

South European countries can face the greatest problems with fruit growing if the predicted temperatures rise continues. Warmer locations require low chilling cultivars that can withstand heat waves during the summer. Changing climate in Norway carries threats of late spring frosts and heavy rains in fall. Cultivation strategies should be developed that meet the needs of the future climate challenges. Limiting risk of unpredictable weather extremes during the vegetation period, growing technologies for new plant species under covers or in high tunnels should be developed. There is experience of cherry growing in tunnels (Meland et al., 2017), while for other fruit trees there is still very limited knowledge worldwide. High tunnels have been widely used in vegetable, flower, and fruit production worldwide (Demchak, 2009). They can advance the fruit harvest season 2 to 3 weeks in summer or extend the season 2 to 3 weeks in the fall without heating equipment (Yao and Rosen, 2011).

The main benefits of changing climate are:

- enrichment of the assortment of cultivated fruit trees by new more tender and/or later ripening cultivars. This process is already noticeable in apple and cherry growing.
- introduction of new fruit species, moving from amateur gardening to commercial growing.

Up to now there is a lack of knowledge and experience with new fruit species in Norway. Only two scientific studies were performed on peach and apricot cultivar evaluation. Nectarine cultivars and possibilities of their cultivation were never tested. Some information provided on grape cultivars in popular scientific journal 'Norsk Frukt og Bær' is based on practical experience from Asker, Oslofjord area (Syversen, 2014; 2019), but these grape cultivars were selected mostly for wine or juice production (Syversen, 2013). All other available information on grape growing in Norway is also dedicated to wine production and is mainly interviews with growers from Telemark or Oslofjord area with the interpretations of journalists. There is also a limited information about some hundreds of apricot trees planted in Lærdal area. Until now outcomes are not available to the other growers and public, the same as from apricot breeding program started 70 years ago (Statens Forsøksgard Njøs, 1971).

Main goal of the project is to justify the possibilities of introduction of new fruit crops namely table/wine grapes, peaches, apricots, and nectarines, thereby increasing biodiversity, farmers income, and consumption of locally grown fruits.

The project implementation was based on literature analysis, questionnaires of growers and scientists, information gathered during the visits to scientific institutions and farmers in Norway, Sweden, Latvia, and Lithuania.

During the project following scientific institutions were visited:

- Njøs Fruit and berry centre, Norway
- Alnarp, Swedish Agricultural University, Sweden
- Latvian Horticultural Institute, Dobele, Latvia

- Lithuanian research centre for agriculture and forestry, Babtai, Lithuania

Visits to apricot (Harald Blaaflat Mundal, Lærdal) and grape (Arild Syversen, Asker) growers were organised.

2 Results and Discussions

2.1 Apricot (*Prunus armeniaca*)

2.1.1 Origin and cultivation

There are three important regions as origin of apricots: Chinese centre (China and Tibet), Central Asian centre (from Tien-Shan to Kashmir) and Near-Eastern centre (Iran, Caucasus, Turkey) (Janick, 2005), although Armenia had been supposed apricot's origin and named as *Prunus armeniaca*. The apricot growing from central Asia reached Italy during the first century, England in 13th and North America in 18th century.

Apricot is produced in 69 countries around the world and production area is more than 560 000 hectares. World apricot fruit production varied between 3.7 – 4.1 million tons in 2018-2020 (www.statista.com/statistics/577467/world-apricot-production). Turkey, Uzbekistan, Italy, Algeria, Iran, Pakistan, Spain, France, and Afghanistan are leading countries (FAOSTAT, 2020). Turkey is leading the world production of both fresh and dried apricot production and its share is 19% of world market. Uzbekistan, Iran, Pakistan and Afghanistan grow apricots mostly for drying, while France, Spain and Italy produce fruits for fresh market. The top 10 producing countries account for 70% of global production.

2.1.2 Breeding

According to apricot main growing regions, they are separated into different eco- geographical groups: Mediterranean apricots, Chinese apricots, apricots of continental Europe and Europe-North American apricots.

Apricot cultivars from the Central Asian are mostly self-incompatible, but cultivars from the European group are mostly self-compatible and create a major part of commercially cultivated cultivars (Hormaza et al., 2007; Herrera et al., 2018). In recent years, some breeding programs included self-incompatible cultivars from North America to incorporate apricot resistance to sharka (Zhebentyayeva et al., 2012) and it leads to the development of new self-incompatible cultivars and their cultivation in the orchards.

Most of apricot breeding programs are devoted to climate adaptation: a longer development of flower buds, requirement of longer chilling period and higher degree of sum of active temperatures for bud break and flowering. Delaying of flowering time is crucial for apricots which is the earliest flowering stone fruit tree and suffers severely from spring frosts. Late flowering cultivars may escape spring frosts in the regions where they occur. Another important goal of breeding programs is to create cultivars adapted to humid growing conditions and diminish losses due to fruit rots.

2.1.3 Apricot cultivation and research in Northern countries

Apricot is a marginal crop in the Northern countries, and it is grown only at amateur level. Apricot breeding was started in Latvia and Estonia in 1950's. Significant results were produced by Latvian breeders P. Upitis in Dobele, Latvian Horticultural Institute and V. Varna at Botanical Gardens, University of Latvia. Breeding material from Caucasus, Central Asia mountain areas and the northern frontier of apricot cultivation in Europe was used. Five winter hardy apricot cultivars Daiga, Lasma, Velta, Jausma and Rasa were released from both breeding programs (Kaufmane and Lacis, 2004). Unfortunately, apricot breeding programs were terminated and only cultivar evaluation is taking place in a small extend in Latvia and Lithuania. Apricot cultivar evaluation trials are not performed in

Denmark, Sweden or Estonia, judging that there are no scientific reports and papers published on this topic.

2.1.4 Apricot research and cultivation in Norway

2.1.4.1 Research

Apricots have been grown in Norway for a long time in amateur gardens. Yields were varying and fruit quality was not sufficient and lacking taste. In 1950's apricot breeding was started at Njøs fruit research station and from 1965 most promising seedlings were planted in the test fields. However, none of these selections was named as an apricot cultivar. In this period some foreign cultivars were tested, but none of them were recommended for commercial growing.

Another outcome was from plantings at Ullensvang Research Centre from 2006, when 10 different varieties of apricot were planted. Apricots are more adapted to Norwegian growing conditions than peach or nectarine, due to lower sensitivity to fungus diseases.

It was established that apricot cultivars Goldrich, Pincot, Sylred, Harcot, Hargrand and Orangered are self-sterile and need a pollinizer.

Cultivars Hongaarse, Wczesna z Morden, Hargrand, and Henderson were lacking taste, exhibited fruit splitting and other limitations.

Later flowering cultivars were Tros Orange, Orangered, Goldrich, Pincot, Sylred, and especially late was Nancy.

Cultivars Orangered, Kuresia, Pinkcot, and Bredase had the best fruit taste, and among them Orangered accumulated the highest content of soluble solids (Kvamm-Lichtenfeld et al., 2013). Gold Cott and Harcot were the most precocious.

2.1.4.2 Cultivation and growers experience

At this moment, 2 500 – 3 000 apricot trees are cultivated in commercial orchards in Lærdal. First commercial apricot orchards were planted in 2011. Orangered and Pinkcot were propagated on rootstocks St. Julien A and Wavit. Despite of big fruits and good appearance, the taste score of Pinkcot fruits was very low. It is interesting that in the trial performed at Ullensvang, Pincot was rated among cultivars with the best taste. Such differences point again at the necessity to evaluate cultivars in different sites with different microclimate conditions.

New orchards were established in 2013. Apricot cultivars from Cot series were planted: Wondercot, Ladycot, Magiccot, Pinkcot, Perlecot, Tomcot, Sunnycot and Flavorcot, on semi dwarfing plum hybrid rootstock Torinel (Hernandez et al., 2010) compatible with plums and apricots, but not compatible with most of peach and nectarine cultivars and apricot seedling rootstock Manicot (Duval et al, 2012). The yield of these cultivars was relatively low, and fruits were lacking taste. Early ripening Wondercot performed best of all Cot cultivars, but more time is needed to make conclusion on its adaptability to Norwegian climate and growing conditions. Cot series cultivars are largely promoted in UK, especially Tomcot, Gold Cott and Flavorcot as very productive with excellent fruit quality in cooler climate, however in Germany Cot cultivars are not performing well.

Figure 1. Commercial apricot orchard in Lærdal. Photo: Darius Kviklys, NIBIO.

The newest plantings at Lærdal included French cultivars from INRA breeding program self-fertile, late flowering Bergeval and self-fertile Vertige, German cultivar Kuresia, Canadian cultivar Hargrand and Goldrich from US.

As a result of cultivar evaluation in commercial fields, Kuresia, Bergeval, Vertige and Orangered were selected as the most favourite cultivars in Lærdal.

Figure 2. Bearing apricot tree in Lærdal. Cultivar Goldrich. Photo: Ivar Petter Grøtte.

2.1.5 The main challenges of apricot cultivation in Norway and prevention measures.

Very early flowering. Frost damages. Depending on the cultivar apricots can withstand temperatures minus 20°-25°C during the winter. During the flowering time 10% of flowers can be lost at -2.5°C, and 90% at -5.6°C. Fruitlets are even more sensitive and 10% dies at -0,5° and 90% at -4.4°C.

The results of scientific study showed a different degree of cold tolerance according to the genotype and the phenological stage. After the break of endo-dormancy and at the pre-flowering stage, when flower buds are generally more susceptible, some genotypes ('Haggith', 11/48/2, 7C/20/3, 2/29/11) were hardy, not only at -4°C, but also at -8°C (Guerriero et al., 2006). Such promising findings let intensify search for the frost-hardy genotypes.

To avoid risk of very early flowering of apricots, priority should be given for the introduction of late flowering cultivars.

All measures delaying flowering or protecting flowers from frost damages must be employed.

Application of ethephon and gibberellic acid aminocyclopropane 1-carboxylic acid, abscisic acid, and soybean oil was tested to delay apricot flowering (Laňar et al., 2022; Ganji Moghadam and Mokhtarian, 2006), however the results were contradictive, and sometimes had negative effect on fruit set and the yield.

Cultivation of apricots under plastic covers or in high tunnels is another solution for the creation of milder environment during the tree flowering.

Very early flowering. Complicated pollination. The earliest apricot flowering recorded in Lærdal was even on April 2nd, when no flower pollinating insects are flying.

To overcome this challenge, attention should be paid to self-fertile apricot cultivars. If apricots are cultivated in high tunnels, bumble bees can be employed for the pollination.

Disease and pest control. One of the biggest problem growers are facing is fruit rots. No chemicals for disease as well as pest control are registered in Norway for apricots. Most of chemicals used for disease and pest control in cherry and plum orchards perform excellent for apricots as well, but due to very limited orchard acreage chemical companies are not interested to enlarge registration. Cool and humid weather during the vegetation period is causing fast development of fruit rots. The most spread disease is apricot brown rot which is caused by the fungus *Monilinia fructicola*. The first infection occurs during the flowering and dying blossoms are the first symptoms of the disease. From the infected flowers it enters to the twig and causes dye back of the shoot. If maturing fruit is infected, a small brown rotted spot is a symptom of the disease and later fast spore growth damages the whole fruit.

Figure 3. Dye back of the apricot shoots in Lærdal. Photo: Darius Kviklys, NIBIO

Another major disease is apricot scab. Scab on apricot is caused by the fungus *Cladosporium carpophilum*. Black spots reduce marketability of the fruits. If the disease is not controlled, large areas of the fruit will show lesions, exposing the pulp to many fungi which cause fruit rots. Twigs and leaves may also be infected, but fruit infection is more common.

To prevent diseases, it is very important to ensure as quick as possible drying of foliage and fruits after the rain or morning dew. Disease damages differ according to the tree training systems. Apricot trees are strong growing, with long shoots and large dense foliage. If the trees are trained as central leaders, wet leaves and humid conditions inside the crown is kept for very long time during the day and, in such conditions, diseases cause severe fruits damages. Open vase training system, though it is old style, but still largely used in apricot growing regions around the world, provides much better microclimate inside the crown due to better illumination and air circulation. Only some rot damages were noticed in one of apricot orchards, trained as open vase in Lærdal area, whereas central leader orchards faced with extensive rot damages.

If pesticides for apricots will be registered in Norway, chemical treatments should be applied already just before flowering and during the full bloom and repeated every two weeks during the fruit growth. As a rule of all fungicide treatments, full coverage of fruits is important. Insect control should be maintained properly, since small insect damages can serve as entry points to the fungus.

Fruit scab is a minor disease if chemical treatments are applied.

Cool weather during the vegetation. 'Typical Norwegian summer' - cool and humid - cannot provide sufficient amount of heat hours to achieve proper fruit taste qualities.

Can long Norwegian day compensate lack of temperatures? There are some speculations and insights with other crops, however detailed research should be performed.

To dimmish negative effect of cool weather only early ripening cultivars should be cultivated. Cultivars adapted to continental climate (North US, South of Canada) should not be planted in Norwegian fjord areas.

Growing in high tunnels can be another solution, but scientific studies must be performed. According to apricot growers, one year apricot fruits grown in plastic tunnels did not gain colour and remain yellow when ripened. Carotenoids are responsible for the apricot yellow orange colour, while red blush present in the skin due to biosynthesis and accumulation of anthocyanins. Research demonstrated that

blush formation on apricot fruits depends on light (Xi et al. 2019), and tunnel conditions could negatively affect illumination, especially in the season with less sunny hours.

Rootstocks. Norwegian growers have very little or no experience with apricot rootstocks. Trees are propagated on St. Julien rootstock mainly and some on Wavit rootstock. Worldwide apricot is mostly grafted on the seedling rootstocks (Duval et al., 2012). Most of these rootstocks belongs to the same species, but also Myrobalan seedling rootstock and its clones (Myrobalan B, Myrobalan 29C) are widely used. Apricots are vigorous tree and need more dwarfing rootstocks (Hernández et al., 2010). Plum rootstock St. Julien A is used widely for apricots, but it is still not enough dwarfing. Much smaller apricot trees grow on other plum seedling rootstocks Wavit and Weiva and they are extensively used in some European countries. Recently, dwarf Krymsk rootstocks are widely tested and recommended, especially Krymsk 1 (Prunus tomentosa x Prunus cerasifera) (Skřivanová et al., 2020) and Krymsk® 86. There is a big choice of rootstocks for apricots, however studies of rootstocks adaptation and performance at Norwegian growing conditions must be performed.

Marketing problems. Customers are not familiar with apricots, especially if they are from Norwegian orchards. There is no demand for apricots from supermarkets. Even in direct sell from the farm, customers prefer plums instead. Until now restaurants are the main buyers, but with enlarging areas and expected higher yields, restaurants will not be able to process all fruits.

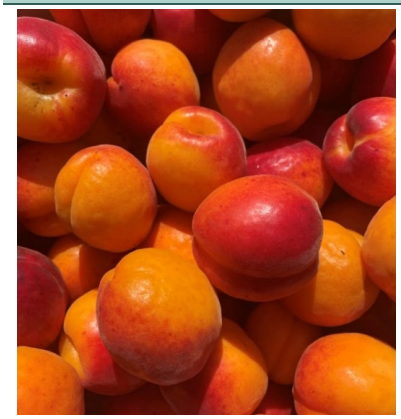
Postharvest. Another marketing challenge is that there is a lack of knowledge about fruit harvest time and their shelf life at Norwegian conditions. Though, there are some indications that fruits of some cultivars can be stored successfully in the cold storage for extended period.

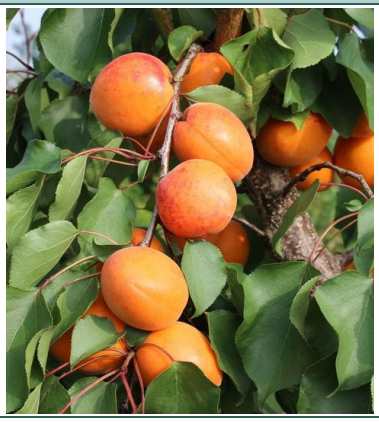
2.1.6 Recommended apricot cultivars.

Besides fruit quality characteristics and eating value, winter hardiness and late blooming are the main requirements for the proper cultivar choice.

Table 1. Apricot cultivars recommended for planting and variety evaluation trials.

Recommendation	Fjord regions	Inland regions
Planting	Bergeval, Kuresia, Orangered, Vertige	-
Variety evaluation	Bergarouge, Candide, Gold Cot, Goldrich, Flavorcot, Harglow, Harojoy, Harostar, Puget Gold, Tomcot, Wondercot	Gold Cot, Flavorcot, Harcot, Harojoy, Haroblush, Hargrand, Kioto, Tomcot, Puget Gold, Wondercot,

Orangered	Kuresia	Bergeval
		
Origin: US Flowering: early Ripening: mid-season Medium large fruits Self-sterile Photo: Harald Blaaflat Mundal	Origin: Germany Flowering: early Ripening: late Medium sized fruits Self-fertile Photo: Oddmund Frøynes, NIBIO	Origin: INRAE, France Flowering: late Ripening: mid-season Large fruits Self-fertile Photo: https://catalogue.starfruits-diffusion.com/variete/bergeval-aviclo/

Vertige	Puget Gold	Candide
		
Origin: INRAE, France Flowering: late Ripening: mid-season Medium large fruits Self-fertile Photo: https://catalogue.starfruits-diffusion.com/variete/vertige/	Origin: WSU, US Flowering: early Ripening: late Large fruits Self-fertile Photo: https://raintreenursery.com/collections/apricot-trees/products/puget-gold-apricot-lovell	Origin: INRAE, France Flowering: late Ripening: mid-season Large fruits Self-fertile Photo: https://www.graeb.com/en/range/apricots/maturity-table/candide-s/#lightbox[1953]-2

Goldrich	Bergarouge	Wondercot
		
Origin: WSU, US Flowering: mid early Ripening: mid late Self-sterile Large fruits Resistant to fruit split Photo: Oddmund Frøynes, NIBIO	Origin: INRAE, France Flowering: early Ripening: mid late Partly self-sterile Large fruits Photo: https://catalogue.starfruits-diffusion.com/variete/bergarouge-avirine/?lang=en	Origin: US Flowering: early Ripening: early Medium size fruits Self-sterile Photo: https://anfic.com.au/variety/wonder-cot-apricot

Hargrand	Gold Cot	Harcot
		
Origin: Ontario, Canada Flowering: early Ripening: mid late Partly self-fertile Very large fruits if thinned Photo: Oddmund Frøynes, NIBIO	Origin: US Flowering: early Ripening: mid late Self-fertile Medium size fruits Resistant to leaf spot. Photo: Oddmund Frøynes, NIBIO	Origin: Ontario, Canada Flowering: late Ripening: mid-season Self-fertile Medium large fruits Resistant to brown rot and perennial canker, tolerant to bacterial spot Photo: Oddmund Frøynes, NIBIO

Gold Cot	Harglow, Haroblush, Harojoy, Harostar	Flavorcot, Tomcot	Kioto
	Origin: Ontario, Canada Flowering: early (Harglow late) Ripening: mid late Medium size fruits Self-fertile Haroblush moderately resistant to bacterial spot, and skin cracking Harojoy tolerant to bacterial spot, brown rot, and skin cracking Harostar resistant to bacterial spot, brown rot, and skin cracking	Origin: WSU, US Flowering: early Medium size fruits Self-fertile Flavorcot ripening mid-season, fruits need thinning Tomcot ripening early, not cracking fruits	Origin: Escande, France Flowering: late Ripening: early Self-fertile Medium size fruits, needs thinning
Origin: US Flowering: early Ripening: mid late Self-fertile Medium size fruits Resistant to leaf spot. Photo: Oddmund Frøynes, NIBIO			

2.2 Peach and nectarine (*Prunus persica*)

2.2.1 Origin and cultivation

Peaches and its smooth skin mutant nectarine [*Prunus persica* (L.) Batsch] are native to Tibet and South West China and their cultivation started already at least 4 000 years ago. Peaches and nectarine are well adapted to temperate and sub-tropical regions, and mostly are cultivated between latitudes of 30° and 45°.

World peach and nectarine production averages 24-25 million tons. China is the largest producer with 14-15 million tons, followed by EU and Turkey. In recent years Turkey become the world leading peach and nectarine exporting country.

Around 90% of total EU peach and nectarine is produced in Spain 1.4 -1.5 million tons, Italy 0.9-1 million tons and Greece 0.9 million tons.

Nectarines are considered as substitute for peaches and, recently, new plantings overcome plantings of peaches in top producing countries.

According to geographical distribution, the peach cultivars have been divided into three groups: Northern, Southern and European or Persian group.

2.2.2 Peach and nectarine cultivation and research in Northern countries

There are no commercial plantings of peach and nectarines neither in Scandinavia, neither in Baltics.

Breeding of peach was done by V.Vārna at Botanical Gardens, University of Latvia. In 2004 two cultivars were registered – Maira (propagated under the name Riga) and Viktors. At present peach breeding is not continued, but 2 elite seedlings have been selected at Pure (Latvian Horticultural Institute) (Kaufmane and Lacis, 2004).

No scientific papers or reports were published about cultivar evaluation in other Nordic countries, indicating that peach and nectarine studies were conducted in very limited extend or were not performed at all.

2.2.3 Peach and nectarine research and cultivation in Norway

There are no commercial plantations of peach and nectarine in Norway.

Only one cultivar testing was performed at NIBIO Ullensvang in 2006 – 2012. Self-fertile peach cultivars Amsden, Amsden June, Benedicte, Champion, Charles Ingouf, Frost, Harnas, Revita, Reliance, Red Haven, Riga, Peregrine, and Vaes Oogst, originated from Belgium, Latvia, US, UK, Canada, France and Germany and propagated on 'St. Julien A' rootstock were tested. Main features of these cultivars were early maturation, winter hardiness and late flowering time.

Canadian cultivar Harnas had the best fruit quality, though the yield was not consistent, and trees were extremely susceptible to peach leaf curl. Latvian cultivar Riga had the highest yields throughout the trial period; however, its flowering time was the earliest. No one of tested cultivars reached proper yield, comparing to the yields in peach producing countries. None of tested cultivars was recommended for commercial plantings in Ullensvang, Norway, in the open fields, but Harnas and Riga can be suitable for the growing in tunnels.

Peach leaf curl (*Taphrina deformans*) was the main disease affecting production in the tests. Reliance, Charles Ingouf, Champion and Harnas were especially sensitive. Infection of these cultivars was rated even 7-9 points in 1–9 point scale.

Figure 4. Redhaven peach at Lærdal. Photo: Ivar Petter Grøtte

2.2.4 The main challenges of peach and nectarine cultivation in Norway and prevention measures.

Very early flowering. Frost damages. Similarly to apricots, peach and nectarine trees have very early flowering when there are no pollinating insects and possible spring frost can kill flowers and reduce the yield. Additionally, peaches and nectarines are among the most sensitive to winter injury fruit species. Selection of orchard sites with mildest climate is important. Also, the root systems require a well-drained soil.

Some of peach and nectarine cultivars can withstand minus 25°C in the dormant stage, but the temperatures around -7°C at the budbreak damages flower buds. One of the biggest problems can be extended warm periods in the late winter and early spring, when tree dormancy (and natural hardiness) can be broken and following frost can damage not only flower buds but also kill the entire tree. The minimal temperature during the flowering is -4°C, but fruitlets can be damaged at -1°C. However, results of a study with nearly a hundred accessions and cultivars of peach, indicate that there are cultivars with increased freeze tolerance (Melgar et al., 2022).

When peaches flower, there are very few pollinating insects. Hand pollination by paint brush pressing it into every flower is recommended.

Cool weather during the vegetation. According to Wurm et al. (2002) the limit for peach production is an average temperature of 8°C per year and according to Ohlinger (2008) the average daily temperature in July should be +18°C. In contrast, Ullensvang has an average yearly temperature about 6.8°C and an average daily temperature in July about 15°C. Only early ripening cultivars can be cultivated in Norwegian climate conditions. The same as for apricots, growing peaches and nectarines in high tunnels is possible, but scientific studies must be performed.

Rootstocks. Peaches and nectarines are naturally exhibiting lower vigour and more compact crown and even on vigorous rootstocks can be managed in intensive orchards.

Traditionally, peaches and nectarines were mostly grafted on their seedlings, but these rootstocks have several problems like late bearing, variability, vigorous growth, etc. Peaches are very prone to

nematode attacks and are severely affected by several soil nematodes such as *Meloidogyne* spp., *Pratylenchus* spp., *Xiphinema americanum*, and many soil-borne pathogens like *Phytophthora* spp., *Armillaria* spp., *Verticillium* spp., *Agrobacterium tumefaciens*, etc.

The American NC-140 project evaluated peach rootstocks for 40+ years (Reighard, 2022). Coordinated peach rootstock testing began in 1984, 6 trials were implemented, and overall, 53 rootstocks were evaluated. Peach seedling rootstocks were often better performers, but recent trials of non-seedling propagated cultivars have been promising, which has encouraged increased planting of clonal rootstocks for peach in North America. The last completed trial in 2009 at 16 locations with 18 rootstocks included interspecific hybrids. Peach and peach hybrid rootstocks were the most vigorous and productive, while the Controller™ series and plum rootstocks were the most yield efficient. In the north-eastern US, 'Controller™ 7 and 8' showed superior performance to the traditional peach rootstocks. The hybrid 'Krymsk® 86' had a superior performance on high pH soils.

In all multisite rootstock trials significant differences were observed among rootstocks and locations for most horticultural traits (Minas et al., 2022; Reighard, 2022), leading to the conclusion that rootstock research should include studies of rootstock scion combinations and studies of rootstock adaptiveness to the specific site conditions across Norway.

Disease and pest control. Peach Leaf Curl. The most serious disease of peaches and nectarines is Leaf curl, caused by the fungus Taphrina deformans. Leaf curl attacks blossoms, leaves, current year's twigs, and fruit. Infection is promoted by cool, wet weather during early spring that retard tree growth more than growth of the fungus. A reliable strategy for Leaf curl pest control in a wet, suboceanic climate (Western Norway) is not yet established. The most successful control of Leaf curl was done at Ullensvang in 2010 with multiple treatments with copper and Delan from early April until June and removal of infected leaves.

Figure 5. Symptoms of Peach leaf curl. Photo: https://extension.okstate.edu/fact-sheets/leaf-curl-of-peaches-and-nectarines.html.

Site selection. In order to avoid stem cracking in the winter and delay the flowering of peach and nectarines trees, northeast slopes are recommended. North slopes provide more even temperature conditions during the winter, avoiding sharp temperature fluctuations between sunny days and nights, which is a reason for bark splitting and heavy trunk injuries leading to tree death.

Cooler conditions keep longer trees in dormancy and later flowering in northern slopes is expected.

2.2.5 Recommended peach and nectarine cultivars for variety evaluation trials.

All peach and nectarine cultivars should be properly evaluated before establishment of commercial plantations. The hardiest nectarine cultivars can be tested in fjord regions, meanwhile no nectarine cultivars were selected for inland regions.

Table 2. Peach and nectarine cultivars recommended for variety evaluation trials.

Species	Fjord regions	Inland regions
Peach	Harrow Dawn, Rochester, Redhaven, Vee Blush	Harrow Dawn, Vee Blush,
Nectarine	Harovin Rouge, Harblaze, Harflame	-

Rochester	Vee Blush	Harrow Dawn
Origin: US	Origin: Canada	Origin: Canada
Flowering late	Ripening: mid late	Ripening: mid-season
Ripening: late	Medium size fruits	Medium size fruits
Medium size fruits	Good resistance to leaf spot	Medium-high field tolerance to bacterial spot, brown rot and canker

Nectarine Harblaze	Nectarine Harovin Rouge	Nectarine Harflame
Origin: Canada	Origin: Canada	Origin: Canada
Ripening: mid late	Ripening: late	Ripening: late
Medium sized fruits	Medium large fruits	Medium large fruits
Medium susceptibility to bacterial spot.	Tolerant to canker and highly tolerant to bacterial spot and brown rot	Medium susceptibility to bacterial spot.

2.3 Grape (*Vitis* sp.)

2.3.1 Grape cultivation and research in Northern countries

Sweden. Sweden was appointed as EU official wine country in 1999. There is a lack of tradition and experience of commercial cultivation of grapes, but Sweden has already 300 vineyards including 25 commercial vineyards approved by the authorities. Vineyard area in South of Sweden reached already 170 ha and the area of the largest plantations is 16-18 ha. Almost all of vineyards are established nearby to seacoast line. Microclimate conditions near the sea delay bud break and prolong vegetation period.

Growing season (>4°C) in South of Sweden is longer than in Norway and lasts 220 days, with the 0°C mean temperature in February, and around 17°C in July and August. One of the challenges is spring frost. Budbreak of plants starts at the end of April, shoots reach 5-7 cm in the middle of May, and spring frost can kill buds or new shoots. If a primary bud is frozen, shoots emerge from the secondary buds, however they produce very small or no yield. If primary shoots develop 3-4 clusters, the secondary shoots develop only 1-2 clusters of worse quality. Spring frosts are controlled by windmills or candles.

Differently from Norway there is a dominance of *Vitis vinifera* cultivars and hybrids with *V. vinifera* in Sweden. New cultivar evaluation trials include Pinot Nova, Pinotin, Cabernet Jura, Vanessa, Venus, Riesel, Kristall, Cabernet Noir, Cabernet Blanc. Recently the focus is on PIWI cultivars, which are resistant to main fungal diseases. Vanessa and Venus are two PIWI cultivars which can be grown as table grapes too.

Solaris is the most widely planted cultivar. It was established that 1 000 degree hours over 10°C are necessary for Solaris grape maturation. For full bloom – 294, to reach pea size – 617, for veraison (change of colour of the berries) – 802 degree hours.

Differently from Norway, cv. Rondo is not cultivated due to low taste scores of wines. In order to avoid phylloxera attacks, all *V. vinifera* plants are grafted on rootstock SO4, a crossing between *Vitis berlandieri* and *Vitis riparia*.

It was established that cultivars from USA and Canada are very winter hardy and can stand temperatures down to minus 25°C but requires hot weather during the summer. These cultivars usually do not reach proper quality, though could be interesting to test them in more continental climate conditions. The same observations were done at Norwegian conditions too.

It is recommended to establish plantations at 3 x 1.2 m distances and train in Guyot system (double or single). 7-8 leaves should be left above the fruit cluster. High vines require broader distance between rows to eliminate inter shading, but broader distance is decreasing yield per area.

Irrigation of vines is not necessary, maybe only during the first years of establishment.

Though no studies have been done yet but growing of table grapes in the high tunnels could be very perspective.

Denmark. Denmark was appointed as EU official wine country in 2 000. The Danish Vineyards Association (from 2017 The Association Danish Wine) was established in 1993 and now have around 1500 members, more than 100 of them have commercial vineyards. Area of commercial vineyards is more than 100 ha and produce more than 100 000 litres of wine. Location and microclimate are very important, thus grape growing is concentrated mainly near coastline or islands in four main regions Jutland, Funen, Zealand and Bornholm. Coastline areas have no spring frosts, more sunny conditions, but cooler summers, when inland areas experiences spring frosts, but have higher temperatures during the growing season.

Early maturing Rondo is the most important grape cultivar for producing red wine. Oher two important red wine cultivars are Leon Millot and Regent. Initially red wine production was dominating, but in recent years growers are focusing on white and sparkling wine, thus Solaris is the most important cultivar for producing white wine (Becker and Toldam-Andersen, 2012).

According to the studies done at the University of Copenhagen in cold wine climate to reach proper quality, leaf/fruit ratio should be 20 cm^2/g fruit, when in cool wine climate 15 cm^2/g fruit and in warm only 10 cm^2/g fruit (https://vitinord2012). Correspondingly, in Denmark (or Scandinavian countries) the yield will be lower if grapes will be trained in similar way as in main wine producing regions or higher canopies with more leaves must be maintained. If the average leaf size is 250 cm^2, approximately 12 leaves are needed to grow the cluster of 150 g. For additional 25 g two leaves should be added. Following these studies, further recommendations are provided: keep one cluster per shoot, do not plant cultivars with the large clusters or prune the clusters.

Denmark is the leading scientific research environment in North of Europe in vineyard management and wine properties. Flavour properties of Danish wines from cultivar Solaris have been studied by Liu et al. (2015). The effects of water deficit, defoliation, and crop-thinning on Solaris plants and fruit development, as well as on the chemical composition of grape juice (Aru et al., 2022a) and wine (Aru et al., 2022b) were investigated.

Lithuania. Lithuania was appointed as EU official wine country in 2022. Comparatively fast enlargement of grape growing was noticed during the last decade and the area reached more than 50 ha in 2021. First plantations were established predominantly by Lithuanian and Latvian grape cultivars. Still some Lithuanian cultivars as Juodupe and Varduva have a place in the new plantings, but other cultivars as Solaris, Rondo, Regent, Marechal Foch, La Crescent, Leon Milot, Adalmina are planted too. Due to cold winters, when the temperature can drop down to minus 25°C, winter hardy American, Canadian and German cultivars are the main choice. According to the scientists, white wine cultivars have better adaptation to Lithuanian climate conditions. Lithuanian and Latvian cultivars are more sensitive to mildew (https://ukininkopatarejas.lt/vynuoges-vilioja-daugeli-bet-jas-augintinelengva; https://www.tv3.lt/naujiena/gyvenimas/ilzenbergo-dvaro-vynuogynas-cia-vynmedziai-gali-atlaikyti-ir-spengiancius-salcius-n1118487).

Regarding table grapes the most popular cultivars are Arkadija (Ukraine), Esther (Hungary) and Varduva, seedless cultivars Somerset seedless, Jupiter and Reliance. All of them can be cultivated in the open field, though, usually table grape cultivars are more sensitive to cold during the winter and requires higher temperatures during the vegetation to achieve proper quality and good maturity. More sensitive cultivars are recommended to grow in the greenhouses.

Lithuanian scientists and growers do not believe that grape growing will guarantee stabile income to the farmers. The main market for the locally produced wine will be rural tourism, degustation during the events and fairs, or selling as souvenirs. The main market for table grapes and juices will be street market and farmer's market.

Latvia. Area under the grapes plantings in Latvia is around 25 ha and mostly only cultivars of Latvian origin are planted.

The Latvian breeders released several grape cultivars for outdoor growing, using for breeding genotypes of *Vitis vinifera, V. labrusca* and/or *V. amurensis*. All Latvian cultivars are very early ripening and winter-hardy. The first cultivars 'Guna', 'Sukribe', 'Supaga', 'Zilga' were released by P.Sukatnieks, and have been widely planted, however, in recent years they increasingly suffer from downy mildew. The newest grape cultivars 'Dovga', 'Liepājas Dzintars', 'Liepājas Agrā', 'Cīravas Agrā', 'Silva' are released by G.Vesmiņš (Vesmins et al., 2016).

2.3.2 Grape research and cultivation in Norway

At this moment in Norway there are more than 40 000 grape plants cultivated by around 100 producers, but most of them are at amateur level with an average of 200 vines. Now, there are 10 commercial plantations mainly in the vicinity of Oslofjord. Approximately 90% of area is dedicated for wine production and 10% for fresh consumption.

Extensive cultivar testing was started 15-20 years ago by Arild Syversen and significant number of grape cultivars were tested during this period. According to him the main problem for grape cultivation in Norway is not a lack of winterhardiness of grape cultivars, but to cool summers. Tested American and Canadian cultivars are winter hardy but requires hot summers for optimal ripening. All of them are better suited to continental climate. It seems that the adapted cultivars under Norwegian climatic conditions are released in countries with similar maritime climate. Of course, there are exceptions, and some Russian or American cultivars perform very well. The most popular wine grapes are Solaris (Germany), Rondo (former Czechoslovakia and Germany), and Hasanskij sladkij (Russia). Other perspective grape cultivars like Leon Millot, Cabernet Cortis, and early Pinot noir are under evaluation. Some of growers took a risk and planted late ripening Risling, but proper berry quality, due to too late maturation was reached only in some most favourite hot summers.

Single Guyot training system is applied leaving one (maximum two) cluster per shoot.

Regarding table grape, attention should be paid on seedless cultivars. If cultivar is seedless, berry size or cluster size is not very important for the consumers. According to A. Syversen the best seedless cultivars are Petite Jewel (a complex hybrid grape, consisting of *Vitis riparia*, *Vitis labrusca*, and *Vitis vinifera*), Somerset seedless (bred by Elmer Swenson in Wisconsin, US), and Korinka ruskaja (Russia). Two Latvian not seedless cultivars Guna and Supaga, give good yield and good eating quality in open field too.

So far, no scientific studies were performed on grape cultivar evaluation or grape cultivation in Norway.

2.3.3 The main challenges of grape cultivation in Norway and prevention measures.

Cool weather during the vegetation. Cool and humid summers are not providing enough heat hours to achieve proper berry taste qualities. Long days can only partly compensate lack of temperature.

A good site choice is the first prerequisite for the successful grape cultivation. Only south slopes must be used, to get as much as possible sun light and grow plants at the warmest places.

All other measures increasing temperature should be adapted too. Most of plantations are planted on black plastic soil cover which increases soil temperature up to 5°C and increases the temperature and creates better microclimate around the clusters. In addition, low training keeping clusters 30-50 cm from the ground should be applied.

Figure 6. Grapes planted on black plastic cover in A. Syversen plantation. Photo: Darius Kviklys, NIBIO.

Leaves that give shade to the clusters must be removed. Also, optimal planting distances (3 m between rows) for the fruiting wall which is usually maintained up to 1,5 - 2 meters high in Nordic conditions should be chosen. Narrower interrow gives shading to neighbouring plants and decreases berry quality and slows down maturation processes.

The other essential prerequisite for limiting effect of cool weather is cultivation of early ripening cultivars.

Growing of table grapes in high tunnels or greenhouses may significantly improve microclimate and can create possibility to cultivate later ripening cultivars, however, until now fast spread of diseases under protected environment is the biggest challenge. Good air circulation around clusters diminishes risk of berry rots and incidences of mildew, but it is more complicated to provide such conditions in the tunnels or greenhouses.

Early autumn frost damages. There was recorded that early frost in November is damaging buds, herewith, reduces the next year yield. To avoid frost damages, cultivars with earlier shoot hardening (shorter vegetation period) must be selected and other orchard management technologies (limited irrigation, reduced fertilisation, proper pruning, etc.) enabling earlier growth cessation should be applied.

Late spring frosts. Spring frost is not an issue in the fjord areas, however in the areas where they can occur, emerging shoots can be injured or totally frozen. injuring or freezing down of take place. If shoots from the primary buds are killed, new shoots from the secondary buds develop, but they are significantly less productive.

Late spring frosts usually is controlled by windmills or special candles. Also, cultivation of grapes under protected environment could be a solution to avoid spring frosts.

Disease and pest control. Two major diseases - rots (Botrytis) and mildews (downy and powdery mildew) - causes the biggest losses for the grape growers.

Figure 7. Mildew damages of grape leaves and clusters. Photo: Darius Kviklys, NIBIO.

It is known that commercially grown grapes are the most chemically treated plants among all fruit and berry crops produced in the EU.

Since, there is a very limited choice of chemicals to control grape diseases in Norway, good cultivar selection and proper orchard management is the only way out of this situation. The future belongs to PIWI cultivars which have a high resistance to fungal diseases and allow a significant reduction in the use of pesticides (https://www.wineplant.bz.it/en/grape-varieties/resistant-grapevines/). Also, cultivars with more loose clusters can be considered since they suffer less from fruit rots.

All other measures ensuring quicker leaf and cluster drying after the rain or morning dew should be adapted to limit attacks of fungal diseases.

2.3.4 Recommended table grape cultivars.

Table 3. Table grape cultivars recommended for commercial planting and variety evaluation trials.

Recommendation	Fjord regions	Inland regions
Planting	Esther, Petite Jewel, Somerset seedless, Vanessa	-
Variety evaluation	Birstaler Muscat, Katharina, Kodrianka, Muscat Bleau, Nero, Palatina, Venus	Somerset seedless, Vanessa

Birstaler Muscat	**Palatina**	**Muscat Bleau**
		
Vitis interspecific crossing Origin: Switzerland Ripening: early PIWI cultivar Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/birstaler-muskat-328.en.html	Vitis interspecific crossing Origin: Hungary Ripening: very early PIWI cultivar Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/palatina-329.en.html	Vitis interspecific crossing Origin: Switzerland Ripening: early PIWI cultivar Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/muskat-bleu-327.en.html

Vanessa	**Petite Jewel**	**Somerset seedless**
		
Vitis interspecific crossing Origin: Vineland, Canada Ripening: early-middle Seedless Photo: Aryld Syversen, https://druer.org/Sorter.html	Vitis interspecific crossing Origin: Wisconsin, US Ripening: very early PIWI cultivar Photo: Aryld Syversen, https://druer.org/Sorter.html	Vitis interspecific crossing Origin: Wisconsin, US Ripening: middle Photo: Aryld Syversen, https://druer.org/Sorter.html

Nero	Katharina	Kodrianka	Venus	Esther
Vitis interspecific crossing Origin: Hungary Ripening: early PIWI cultivar	Vitis interspecific crossing Origin: Austria Ripening: early-middle PIWI cultivar	Vitis interspecific crossing Origin: Moldova Ripening: early PIWI cultivar	Vitis interspecific crossing Origin: Arkanzas, US Ripening: early Seedless	Vitis interspecific crossing Origin: Hungary Ripening: early-middle PIWI cultivar

2.3.5 Recommended wine grape cultivars.

Table 4. Wine grape cultivars recommended for commercial planting and variety evaluation trials.

Recommendation	Fjord regions	Inland regions
Planting	Rondo, Solaris, Leon Millot	-
Variety evaluation	Cabernet Blanc, Cabernet Cortis, Cabernet Jura, Cabernet Noir, Cristal, Pinot Nova, Pinotin, Regent, Riesel	-

Regent	**Solaris**	**Rondo**
		
Vitis interspecific crossing Origin: Julius Kühn Institute, Germany Ripening: early-middle PIWI cultivar Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/regent-289.en.html	Vitis interspecific crossing Origin: Freiburg, Germany Ripening: very early Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/solaris-292.en.html	Vitis interspecific crossing Origin: Geisenheim, Germany Ripening: middle Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/cabernet-cortis-282.en.html

Riesel	**Pinotin**	**Cabernet Jura**
		
Vitis interspecific crossing Origin: Switzerland Ripening: early-middle PIWI cultivar Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/riesel-vb-11-11-89-12-290.en.html	Vitis interspecific crossing Origin: Switzerland Ripening: middle PIWI cultivar Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/riesel-vb-11-11-89-12-290.en.html	Vitis interspecific crossing Origin: Switzerland Ripening: middle-late PIWI cultivar Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/cabernet-jura-281.en.html

Cabernet Noir	Cabernet Blanc	Cristal
		
Vitis interspecific crossing Origin: Switzerland Ripening: middle-late PIWI cultivar Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/cabaret-noir-283.en.html	Vitis interspecific crossing Origin: Switzerland Ripening: late PIWI cultivar Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/cabernet-blanc-280.en.html	Vitis interspecific crossing Origin: Hungary Ripening: middle-late Photo:https://www.joniskelis.lt/vynuoges/index.php/nggallery/galerija/vynuoges?page_id=114

Cabernet Cortis	Leon Millot	Pinot Nova
	Vitis interspecific crossing Origin: France Ripening: early-middle PIWI cultivar	Vitis interspecific crossing Origin: Austria Ripening: middle PIWI cultivar
Vitis interspecific crossing Origin: Freiburg, Germany Ripening: middle PIWI cultivar Photo: https://www.rebschule-freytag.de/rebsortiment-details-en-287390/cabernet-cortis-282.en.html		

3 Strategy of the introduction of new species and cultivars into Norway

The first stage of successful introduction of new crops is a comprehensive analysis of scientific and practical knowledge gained in Norway, neighbouring countries and in countries or regions with similar climate conditions. Information on cultivar characteristics and management (e.g., winterhardiness, flowering time, required vegetation length and temperature sum, site and soil conditions, management practices, rootstocks, etc) considering climate changes was explored.

The next stages of introduction are cultivar testing and adaptation of management practices to local climate conditions and market traditions.

Different strategies should be employed for the West, South fjord regions with mild winters, absence of spring frosts, but cool and rainy summer, and inland regions with cold winters, spring frosts, but warmer summers.

According to growers' experience and research performed in Norway, neighbouring countries and in regions with similar climate, grapes (wine and table) and apricots can be successfully grown in Norway. However, peach and especially nectarine are more risky crops. Moreover, all scientific knowledge and growers' experience of new crops is gained in Norwegian fjord areas. How new crops will thrive in inland regions of the country, can only be judged by interpretating results from other countries. Before recommendation of introduction of new species to inland areas, scientific evaluation of new crops and varieties must be initiated.

During the project, the information on cultivar performance was gathered not only from different countries, but also from different orchards and sites in the same growing regions. It was established, that specific soil and microclimate conditions in each site can significantly affect various growth and productivity characteristics of the same cultivar. Based on this information, there is a necessity to make small scale evaluation of generally recommended cultivars in each site before starting commercial growing of this tender species at the specific site.

Cherry growing in high tunnels in Norway is successful and areas under the covers are enlarging every year. This experience should be used for testing of more tender fruit species as apricot, peach, nectarine, and table grapes. There are positive reports on growing peach, nectarine, and table grapes in high tunnels in US, Canada and some other countries, so cultivar evaluation, growing technology trials and evaluation of economics in high tunnels should be performed in Norway before the delivery of final recommendations to the growers for the cultivation of these fruit species.

All discussed fruit species are marginal in Norway. The main features of the recommended cultivars, both for cultivation and variety trials, besides fruit and berry quality and productivity, are:

- Early ripening time
- Disease resistance
- Late flowering of apricot, peach and nectarine
- Self-fertility
- Winterhardiness of cultivars recommended for inland growing regions

References

Aru, V., Nittnaus, A., Sørensen, K., Engelsen, S. & Toldam-Andersen, T. 2022a. Effects of Water Stress, Defoliation and Crop Thinning on Vitis vinifera L. cv. Solaris: Part I: Plant Responses, Fruit Development and Fruit Quality. Metabolites 12. 10.3390/metabo12040363.

Aru, V., Nittnaus, A., Sørensen, K., Toldam-Andersen, T. & Engelsen, S. 2022b. Effects of Water Stress, Defoliation and Crop Thinning on Vitis vinifera L. cv. Solaris Must and Wine Part II: 1H NMR Metabolomics. Metabolites 12. 672. 10.3390/metabo12070672.

Becker, J. R., & Toldam-Andersen, T. B. 2012. The wine industry in Denmark. https://www.researchgate.net/publication/284727777_The_wine_industry_in_Denmark

Demchak, C. 2009. Small fruit production in high tunnels. HortTechnology 19:44–49.

Duval, H., Masse, M., Jay, M. & Loquet, B. 2012. Results of French apricot rootstock trials. Acta Horticulturae 966:37-41. DOI: 10.17660/ActaHortic.2012.966.4

Fruit report. 2020. University of California. (https://ucanr.edu/sites/fruitreport/Rootstocks/)

Fuchs, E., Grüntzig, M., Ernst, I. & Kegler, H. 2001. Comparison of apricot genotypes with different resistance level to *Plum pox virus* (PPV). Acta Horticulturae 550:103-106. DOI: 10.17660/ActaHortic.2001.550.12

Ganji Moghadam, E. & Mokhtarian A. 2006. Delaying Apricot (cv. Shahroudi) Flower Induction by Growth Regulators Application. Journal of Applied Sciences 6:266-269. DOI: 10.3923/jas.2006.266.269

Guerriero, R., Viti, R., Bartolini, S. & Iacona, C. 2006. Parents for spring frost tolerance in apricot. Acta Horticulturae 717:153-156. DOI: 10.17660/ActaHortic.2006.717.31

Hernández, F., Pinochet, J., Moreno, M.A., Martínez, J.J. & Legua, P. 2010. Performance of *Prunus* rootstocks for apricot in Mediterranean conditions. Scientia Horticulturae 124(3):354-359. https://doi.org/10.1016/j.scienta.2010.01.020

Herrera, S., Lora, J., Hormaza, J.I., Herrero, M. & Rodrigo, J. 2018. Optimizing Production in the New Generation of Apricot Cultivars: Self-incompatibility, S-RNase Allele Identification, and Incompatibility Group Assignment. Frontiers in Plant Science 9. DOI=10.3389/fpls.2018.00527

Hormaza, J., Yamane, H., & Rodrigo, J. 2007. "Apricot," in Genome Mapping and Molecular Breeding in Plants. V. 4, Fruit and Nuts, ed C. Kole (Berlin; Heidelberg; New York, NY: Springer) 171–185.

https://gardsdrift.no/2014-aprikos-arkiv/dyrker-aprikoser-i-laerdal/150017 (accessed on 18 May 2022).

https://ukininkopatarejas.lt/vynuoges-vilioja-daugeli-bet-jas-auginti-nelengva (accessed on 10 September 2022).

https://vitinord2012.vitinord.org/wp-content/uploads/2021/01/Toldam-Andersen.pdf (accessed on 18 May 2022).

https://www.delfi.lt/agro/sodinu-auginu/vynuogynai-lietuvoje-plotai-ir-populiariausios-veisles.d?id=90055003 (accessed on 10 September 2022).

https://www.gamberorossointernational.com/news/wine-news/is-the-future-of-wine-in-norway/ (accessed on 18 May 2022).

https://www.regjeringen.no/contentassets/416c222bde624f938710ff36751ef4d6/landbruk-og-klimaendringer---fagnotater-som-underlag-for-arbeidsgruppens-hovedrapport-190216.pdf (accessed on 1 March 2022).

https://www.tv3.lt/naujiena/gyvenimas/ilzenbergo-dvaro-vynuogynas-cia-vynmedziai-gali-atlaikyti-ir-spengiancius-salcius-n1118487 (accessed on 10 September 2022).

https://www.wine-explorers.net/en/travelog/norway-the-northernmost-vineyard (accessed on 12 June 2022).

https://www.winemag.com/2021/02/19/japan-norway-wine-regions-guide/ (accessed on 12 June 2022).

https://www.wineplant.bz.it/en/grape-varieties/resistant-grapevines/ (accessed on 19 October 2022).

Ikase, L. & Lācis, G. 2013. Apple breeding and genetic resources in Latvia. Acta Horticulturae 976:69-74.

Janick, J. 2005. The origins of fruits, fruit growing, and fruit breeding. Plant Breeding Review 25:255–321. Doi: 10.1002/9780470650301.ch8

Kaufmane, E. 1998. Apricot breeding for winterhardiness. Horticulture and vegetable growing. Proceedings of the International scientific conferencePlant 31esistance to abiotic environmental factors, Babtai. Pp. 173-178.

Kaufmane, E., Skrīvele, M., Rubauskis, E., Strautiņa, S., Ikase, L., Lācis, G., Segliņa, D., Moročko-Bičevska, I., Ruisa S. & Priekule I. 2013 Development of Fruit Science in Latvia. Proceedings of the Latvian Academy of Sciences, Section B 67: 71-83

Kaufmane, E. & Lacis, G. 2004. Studies on selection of apricots and peaches with good fruit quality and winterhardiness in Latvia. Journal of Fruit and Ornamental Plant Research 12:321-329.

Kvamm-Lichtenfeld, K., Frøynes, O. & Meland, M. 2012a. Dyrking av fersken og aprikos i Norge. Norsk frukt og bær. 15(1): 14-16.

Kvamm-Lichtenfeld, K., Frøynes, O. & Meland, M. 2012b. Vurdering av ulike ferskensorter i Ullensvang. Norsk frukt og bær. 15 (4):12-15.

Kvamm-Lichtenfeld, K., Frøynes, O., & Meland, M. 2012c. Aprikos. Norsk frukt og bær. 15 (4):30-31.

Kvamm-Lichtenfeld, K., Frøynes, O., & Meland, M. 2013. Vurdering av ulike aprikossorter. Norsk frukt og bær. 16 (1):28-31.

Laňar, L., Scháňková, K. & Náměstek, J. 2022. Searching for new possibilities of bloom delay in apricots. Acta Horticulturae 1344:183-188. DOI: 10.17660/ActaHortic.2022.1344.27

Lederer, M.A., Nielsen, D.S, Toldam-Andersen, T.B, Herrmann, J.V. & Arneborg, N. 2013. Yeast species associated with different wine grape varieties in Denmark. Acta Agriculturae Scandinavica, Section B - Soil & Plant Science 63(1):89-96.

Liu J., Toldam-Andersen T., Petersen M., Zhang S., Arneborg N. & Bredie W. 2015. Instrumental and sensory characterisation of Solaris white wines in Denmark. Food Chemistry 166:133-142. https://doi.org/10.1016/j.foodchem.2014.05.148.

Maul, E., Töpfer, R., Carka, F., Ruisa, S., Ujmajuridze, L. & Failla, O. 2015. Identification and characterization of grapevine Genetic Resources maintained in Eastern European collections. Vitis - Journal of Grapevine Research 54:5–12.

Meland, M., Frøynes, O. & Kaiser, C. 2017. High tunnel production systems improve yields and fruit size of sweet cherry. Acta Horticulturae 1161:117-12.

Meland, M., Frøynes, O. & Kaiser, C. 2014. Evaluation of Peach Cultivars in Cool, Mesic Ullensvang, Norway. HortTechnology 24(5):618-622.

Melgar, J.C., Zhou, Q., Lawrence, B.T., Gasic, K., Preece, J.E. & DeBuse, C. 2022. Tolerance of peach fruitlets to late spring freezes. Acta Horticulturae 1346:191-194. DOI: 10.17660/ActaHortic.2022.1346.25 https://doi.org/10.17660/ActaHortic.2022.1346.25

Minas, I.S., Reighard, G.L., Black, B., Cline, J.A., Chavez, D.J., Coneva, E., Lang, G.A., Parker, M., Robinson, T.L., Schupp, J., Francescato, P., Lordan, J., Beckman, T., Shane, W.W., Pieper, J.R., Sterle, D.G., Bakker, C., Clark, B., Ouellette, D., Swain, A. & Winzeler, H.E. 2022. Establishment performance of the 2017 NC-140 vigor-limiting peach rootstock trial across ten sites in North America. Acta Horticulturae 1346:669-676. DOI: 10.17660/ActaHortic.2022.1346.84.

Nordmark, L., Lindén, J., Skjöldebrand, C. & Hansson, H. 2016. The Nordic Light Terroir. Acta Horticulturae 1115:189-194. DOI: 10.17660/ActaHortic.2016.1115.28, https://doi.org/10.17660/ActaHortic.2016.1115.28

Ohlinger, B., Spornberger, A. & Keppel, H. 2008. Suitability of peach and nectarine cultivars for organic production under pannonic climate conditions in Austria. Proc. 13th Intl. Conf. on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing, 18–20 Feb. 2008, Weinsberg, Germany. 123–126.

Reighard, G.L. 2022. Thirty-three years evaluating rootstocks for peach in the NC-140: what have we learned. Acta Horticulturae 1346:655-660. DOI: 10.17660/ActaHortic.2022.1346.82

Skřivanová, A., Vávra, R., Drahoňová, H., Krńka, B. & Ondráńek I. 2020. Compatibility of apricot cultivars with rootstocks Krymsk-1 and Krymsk-2. (https://www.ecofruit.net/wp-content/uploads/2020/04/55-skrivanova-356-359-1.pdf)

Statens Forsøksgard Njøs 1920-1970 (1971). Hermansverk. 141 pp.

Syversen, A. 2013. Hvitvinsproduksjon i Norge. Norsk Frukt og Bær 16(1):26-27.

Syversen, A. 2014. Dyrking av drueplanter i Asker. Norsk Frukt og Bær 17(1):20-21.

Syversen, A. 2019. Værutfordringer druesesongen 2019. Norsk Frukt og Bær 6:4-5.

Vesmins, G. & Vesmina, L. 201). Ieteicamas lauka vinogu skirnes [Recommended grape cultivars for field]. Agrotops 5:70–72 (in Latvian).

Vesmins, G., Ruisa, S. & Lācis, G. 2016. Grape genetic resources and breeding in Latvia. Acta Horticulturae 1139:117-122DOI: 10.17660/ActaHortic.2016.1139.21

Yao, S. & C. Rosen. 2011. Primocanefruiting raspberry production in high tunnels in a cold region of the upper midwestern United States. HortTechnology 21:429–434.

Wurm, L., Bachinger, K., Rogner J., Schreiber, R., Pieber, K. & Spomberger, A. 2002. Marillen/aprikosen anbau pflege verarbeitung Osterreichischer. Agrarverlag, Leopoldsdorf, Austria.

Xi, W., Feng, J. & Liu, Y. 2019. The R2R3-MYB transcription factor PaMYB10 is involved in anthocyanin biosynthesis in apricots and determines red blushed skin. BMC Plant Biology 19, 287. https://doi.org/10.1186/s12870-019-1898-4

Zhebentyayeva, T., Ledbetter, C., Burgos, L., & Llacer, G. 2012. "Apricot," in Fruit Breeding, eds M. L. Badenes and D. Byrne (Boston, MA: Springer) 415–458.

NIBIO
NORWEGIAN INSTITUTE OF
BIOECONOMY RESEARCH

NIBIO - Norwegian Institute of Bioeconomy Research was established July 1, 2015, as a merger between the Norwegian Institute for Agricultural and Environmental Research, the Norwegian Agricultural Economics Research Institute and Norwegian Forest and Landscape Institute.

The basis of bioeconomics is the utilisation and management of fresh photosynthesis, rather than a fossil economy based on preserved photosynthesis (oil). NIBIO is to become the leading national centre for development of knowledge in bioeconomics. The goal of the Institute is to contribute to food security, sustainable resource management, innovation and value creation through research and knowledge production within food, forestry and other biobased industries. The Institute will deliver research, managerial support and knowledge for use in national preparedness, as well as for businesses and the society at large.

NIBIO is owned by the Ministry of Agriculture and Food as an administrative agency with special authorization and its own board. The head office is located at Ås. The Institute has several regional divisions and a branch office in Oslo.

Cover photo: First row from left: Flowering apricot tree, the apricot cultivar Orangered (photos: Mekjell Meland) and the grape cultivar Rondo (web photo).
Second row from left: The peach cultivar Riga (photo: Mekjell Meland), the grape cultivars Solaris (web photo) and flowering peach tree (photo: Mekjell Meland).

nibio.no