NordGen

PPP-report 2018-2020

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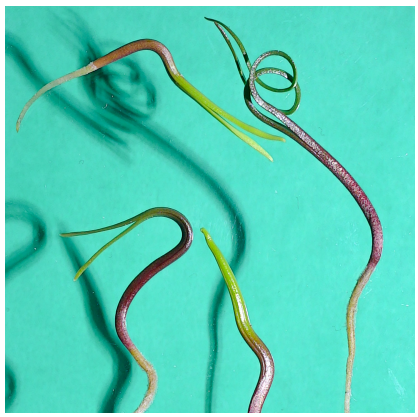
PPP Pre-breeding in the Nordic Collaboration

In the Nordic countries some of the world's northernmost agricultural areas are located. This region covers a widespread geographical area with widely differing environmental conditions for cultivation. Agriculture and horticulture in the Nordic countries require a plant breeding which develops varieties adapted to the particular growing conditions of the high north in terms of a demanding climate.



Plant breeding in the Nordic countries has a long and proud tradition. Over time, structural changes in the seed industry led to fewer Nordic breeding companies and as a consequence increased dependency on large multinational companies. However, the large multinational breeding companies do not directly breed nor have interest in developing adapted cultivars for a small and unique/particular market, such as for the Nordic region. In this context, the first steps were taken to strengthen the Nordic collaboration within plant breeding and the Public-Private Partnership (PPP) for Pre-Breeding was born. The collaboration of this partnership was aiming to promote the development of plant breeding of varieties adapted for the Nordic countries by supporting long-term breeding goals for Nordic agriculture and horticulture through collaborative pre-breeding projects in this pre-commercial part of the breeding chain.

These long-term breeding goals should/shall primarily concern adaptation to climate change, reduction of environmental impacts, and meeting new consumer and market demands. Thus promote sustainable use of genetic resources for food production and agriculture in the Nordic region and to support Nordic policies in the areas of green growth and bioeconomy.

Anders Nilsson and Roland von Bothmer should be mentioned for

their dedicated work with setting up the Nordic PPP for pre-breeding, not least for the formation of this partnership. In 2008, the structure of the collaboration began to form and contacts were made with all the major Nordic breeding companies. Twelve out of thirteen Nordic plant breeding entities decided to join. Though, the companies all were competitors in different regional Nordic markets, there was a mutual understanding of the strong benefits with a common cooperation in the pre-commercial part of the prebreeding process. NordGen was appointed as secretariat and became responsible for the PPP economy and the communication between engaged contacts. Since 2011 public funding from the responsible countries in the respective Nordic countries have been granted and pooled. In 2012 the Steering Committee of the partnership was in place and a fruitful collaboration began.

The work of the PPP pre-breeding program is based on four principles:

- Pooled public funding while allowing some countries to move faster
- Project based participation from plant breeding companies
- Engagement of the best research environments for the respective projects
- 50/50-funding between public sources and industry

The projects within the PPP pre-breeding program have to be of value for the development of Nordic plant breeding, growers and its markets. Subjects identified to be of joint interest are still about broadening the genetic basis for plant breeding, not least important in a context of adaptation to climate change and reduction for environmental impacts. It is also of great importance to introduce specific genes for resistance to diseases and pests, qualities etc. in adapted genetic background. And not least, development of new technologies could contribute to speed up the long breeding process.

This folder compiles information about the four PPP-pre-breeding projects which have been active during the third period between 2018 to 2020 and what is expected to come in the future. The expectations are high but fair – the knowledge from these projects will contribute to a more sustainable and competitive agriculture and horticulture in the Nordic countries by supporting long-term breeding goals through these collaborative pre-breeding projects between Nordic public and private plant breeding entities.

/Birgitte Lund, Chair of the PPP Steering Committee

PPP NORDFRUIT – Pre-breeding for Future Challenges in Nordic Fruit and Berries

Project leader:

Dr. Stein Harald Hjeltnes, Graminor, Norway

Project partners:

Plant breeding entities: LUKE, Finland; Graminor, Norway; SLU, Sweden
Academic institutions: NIBIO, Norway; CU-PLEN, Denmark
Associated partners: Estonian university of life sciences, Estonia; Latvia university of Life Sciences, Latvia; Lithuanian Research Centre for Agriculture and forestry, Lithuania

Project grants:

5.7 mill DKK from the Nordic Council of Ministers

Main goals:

- Validate the genetic pool of apples and strawberries for future Nordic breeding
- Establish cultivar panels in apples and strawberries for future utilization in genome-informed breeding
- Create novel germplasm by species crossing
- Enhance and develop genetic competence and initiate the process of integration of modern genetic tools into the breeding programs

Apples and strawberries are the most important species within the fruit and berry production in the Nordic countries. But the Nordic production is insignificant on the global market and our cultivation climate requires adapted varieties with specific characteristics. Therefore, the Nordic fruit and berry breeders have an important task ahead of them when it comes to identifying genes suitable concerning climate, disease resistance and improved fruit quality. The project PPP NORDFRUIT Pre-breeding for the future challenges in Nordic fruit and berries, has

been contributing to this important work crucial for the future of the Nordic fruit and berry production.

The project has gathered knowledge about fungal diseases and the resistance in the gene pools. This need has increased dramatically due to global warming, consumer awareness and environmental-friendly policies. In apples the main focus has been on European fruit tree canker (*Neonectria ditissima*) and the storage rots (*Neofabraea* spp) and (*Colletotrichum* spp), while the crown rot (*Colletotrichum acutatum*) was targeted in strawberry. Phenotyping followed a developed standardization for production of inoculum and inoculation protocols. A markedly increased throughput was achieved in resistance screening for strawberry crown rot (*Phytophthora cactorum*) in a large hydroponic system at LUKE Piikkiö.

Standardization of phenotyping protocols for fruit quality traits were established and five targeted traits were selected in apples panels. These were: Fruit firmness, soluble solids content, titratable acidity, harvest date and average fruit weight. The panels of apples were genotyped by the Illumina 20K apple Infinium. array and the strawberry panels were genotyped by the Axiom Fana SNP 50 k array. The apple genotyping supplemented a comprehensive genotyping with the same array in germplasm at SLU and CU-PLEN, while the strawberry genotyping was unique and included diverse material and a total of 760 accessions were genotyped. Novel germplasm of strawberries was created by species crossing (*F. virginiana x F. chiloensis*) provided by NIBIO and planted in fields at Piikki. in Finland by LUKE and at Bjørke in Norway by Graminor. This material has been partly genotyped and phenotyped. Elite populations in strawberries from 4 crosses from LUKE and 4 crosses from Graminor, were rised at Graminor and planted at replicated trials at both locations in 2020 in order to study GxE interactions. These materials will be studied in other projects following PPP NORDFRUIT. The new knowledge of the genetics has shown relationships between the cultivars and the first association studies have been performed in order to reveal the relations between genotype and phenotype concerning several phenotypic characters. The consortium has gained knowledge on existing QTL markers and identified promising new associations that might be applicable in future breeding.

The collaboration within the project has led to several scientific articles and the Nordic partners of the project has started a one-year follow-up project on apples.

/Stein Harald Hjeltnes, Project Leader NordFruit

PPP Pre-breeding in Perennial Ryegrass (Lolium perenne L.)

Project leader:

Professor Odd Arne Rognli, NMBU, Norway

Project partners:

Plant breeding entities: Boreal Plant Breeding, Finland; DLF Seeds AS, Denmark; Estonian Crop Research Institute, Estonia; Graminor AS, Norway; Lantmännen ek för, Sweden; Latvia University of Life Sciences and Technologies, Latvia; Lithuanian Research Centre for Agriculture and Forestry, Lithuania

Academic institutions: Aarhus University, Denmark; Agricultural University of Iceland, Iceland; Norwegian University of Life Sciences, Norway

Project grants:

Phase I (2012-2013): DKK 1,571,850; Extension (2014): DKK 987,000; Phase II (2015-2017): 2,169,947; Phase III (2018-2020): 3,064,000, total TDKK: 7,793 (15,586 from PPP and partners)

Main goals:

- Develop improved germplasm of perennial ryegrass with a suitable adaptation to future climates in the Nordic region.
- Develop tools for genomics-assisted future breeding
- Create an arena for collaboration, capacity building and synergy

In Northern Europe, the expected climate changes will result in new growth conditions for forage production due to longer (1-3 months) growth season combined with milder and rainier autumns and winters. To meet the challenges of the future climate, and to move perennial ryegrass further north, the genetic diversity of the Nordic perennial ryegrass breeding populations needs to be enlarged. This pre-breeding project has been running in three phases from 2012 to 2020 and has now been terminated.

The project started by obtaining seed samples of 383 genebank accessions. These accessions were seed multiplied, genotyped by high-throughput sequencing (GBS), established as replicated single plant experiments for detailed phenotyping in Denmark, Sweden, Norway and Finland and the diploid accessions established in crossing blocks in Denmark and Norway for generating a broad-based breeding population. A multi-site field trial for testing the potential winter hardiness of 22 perennial ryegrass cultivars confirmed the need for more robust and stable cultivars with wider adaptations.

Genomic predictions based on data from field experiments with the original accessions in all seven countries have identified a set of ~30 superior accessions across the diverse environments and sets of locally best adapted accessions for each partner. Accessions of Baltic and East European origin seem to have the best potential to contribute to improving winterhardiness. The broad-based diploid breeding population has been subjected to natural selection for two generations in all countries to create locally adapted germplasms. Since tetraploid perennial ryegrass is more winterhardy than diploids, we have generated 1000 new tetraploid genotypes by chromosome doubling. These have been used to establish a broad tetraploid breeding population subjected to natural selection in the same way as the diploid.

A range of synthetic populations have been generated in the project, seeds of these will be stored at NordGen under a Materials in Transition (MIT) agreement. All accessions have been checked for ploidy levels using flow cytometry, and passport data have been updated. The breeding companies have access all genotype and phenotypic data generated in the project. In the last phase of the project, a bioinformatic training workshop was organized for the partners. They should therefore be in a position to utilize the data and establish their own molecular breeding activities.

/Odd Arne Rognli, professor NMBU

Photo: Aakash Chawade, SLU.

6P2 – The Nordic PPP Plant Phenotyping Project – Phase 2

Project leader:

Professor Svend Christensen, Department of Plant and Environmental Sciences, Denmark

Project partners:

Plant breeding entities: Danespo, Denmark; DLF, Denmark; Findus, Sweden; Graminor, Norway; Lantmännen, Sweden; Secobra Recherches, Sweden; Sejet Planteforædling, Denmark
Academic institutions: Agricultural University of Iceland (LBHI), Iceland; National Resources Institute Finland (LUKE), Finland; Swedish University of Agricultural Sciences, Sweden; University of Copenhagen, Denmark
Associate partners: Estonian Crop Research Institute, Estonia; Lithuanian Research Center for Agriculture and Forestry (LAMMC), Lithuania

Project grants:

2018–2020; TDKK 12.195.964 from PPP and Partners

Main goals:

- Developing high-throughput plant phenotyping approaches, based on consumer grade unmanned aerial vehicles (UAV) and camera technologies.
- Linking high-throughput genotyping and phenotyping methods to provide new insights into genotype and environment interactions, thereby creating a strong platform for the development and implementation of cost efficient plant breeding technologies for field applications.
- Facilitate networking and knowledge exchange on plant phenotyping among Nordic plant breeding companies, research institutions and technology providers.

The use of unmanned aerial vehicles (UAVs) and camera equipment for automated field phenotyping is a relatively

low-cost technology with many consumer-grade devices available. It has the potential to contribute to the increased competitiveness of Nordic breeding companies, while also providing manifold returns on investments within a relatively short period. In the 6P2 project we have applied UAVs and remote sensing technologies in a variety of trials to target different traits. Different UAV and cameras have been tested, and large amounts of data have been collected in a collaboration between private and public partners. A new software solution, PlotCut3, has been developed in the project for UAV image management and extraction. The software has been implemented in a free and open-source solution and made available to the partners to exploit the collected data. This has achieved results that are applicable for the plant breeders in their day-to-day operations.

The continuation of the Nordic Plant Phenotyping Network has also been an integral part of the 6P2 activities and has continued to support the development of field phenotyping activities. The network has functioned as a forum for exchanging knowledge and new ideas and has created a solid platform for communication between plant breeders and researchers. The opportunity to include Baltic organizations as associate partners in the project has been a great benefit for the project and has pinpointed where Nordic regional development and closer collaboration is highly relevant.

The collaboration will continue in the Nordic Public Private Partnership Plant Phenotyping Project – Phase 3 (6P3), which has been generously supported by NordGen.

/Lene Rasmussen, Senior Executive Consultant, University of Copenhagen

Combining Knowledge from Field and Laboratory for Pre-Breeding in Barley

Project leader:

Ahmed Jahoor, Head of Breeding and Research at Nordic Seed, Denmark

Project partners:

Plant breeding entities: Boreal Plant Breeding, Finland; Graminor, Norway; Nordic Seed, Denmark; Sejet Plant Breeding, Denmark; Lantmännen, Sweden (Phase I)
Academic institutions: LBHI, Iceland; Luke, Finland; SLU, Sweden; UCPH, Denmark (Phase I)

Project Grants:

2012-2020; TDKK 46,000 from PPP and partners

Main Goals:

- To obtain phenotypic and genetic knowledge of current and future important diseases and adaptive traits for the Nordic region and identify novel genetic resources for those traits.
- To provide homozygous MAGIC progenies segregating for one to several diseases and for traits important for adaptation to the Nordic region.
- To provide breeding tools such as genetic markers associated with resistance and agronomic traits.
- To educate PhD Students and Post Docs.

The PPP Barley project ran for three project phases. In the first phase, existing Nordic germplasm was evaluated for resistance and agronomically important traits such as lodging, heading and maturity. The second phase focused on the identification of genetic resources for disease resistance and agronomic traits in 200 diverse genotypes, comprising landraces, breeding lines and cultivars. In addition, crosses were initiated to develop MAGIC populations for introgression of disease resistance and

agronomically important traits using both landraces and advanced breeding material as donor lines.

This lengthy task continued in the third phase in parallel with phenotyping of the final progenies for disease resistance (scald, mildew, leaf rust, net blotch-net and spot type, Bipolaris) as well as heading, maturity, lodging and height under Nordic field conditions. The third phase also included high-throughput non-invasive precision phenotyping of fast seedling growth under controlled conditions in collaboration with IPK in Germany. Fast seedling growth is related to better weed competiveness and positively related to higher yield. In total 260 adapted breeding lines were screened for digital biomass, chlorophyll content and quantum yield of photosystem II.

Altogether, the three project phases have been very successful, resulting in the implementation of KASP markers for marker-assisted selection within the Nordic spring barley breeding companies. Moreover, it has resulted in the development of eight MAGIC and two bi-parental populations segregating for disease resistance as well as one MAGIC population segregating for early maturity. Phenotypic information of their progenies together with markers associated with these traits provide a valuable resource for the Nordic breeders when breeding for disease resistant and climate resilient spring barley. Hence, breeders can transfer the valuable disease resistance genes from exotic material into their breeding material via marker assisted backcrossing.

/Therese Bengtsson, PhD, SLU

The Way Forward for the PPP

As in other parts of the world, Nordic agriculture faces great challenges in adapting to climate change. The future may bring more of dry spring weather with early drought, warmer summers causing heat stress and wet autumns with pests and diseases to follow. The next generations of farmers will most likely require a much wider spectrum of plant varieties adapted to more demanding cultivation conditions. Food security is a basic need and the Covid 19-pandemic has also taught us not to take a functioning import and export market for granted and the issue of a higher degree of selfsufficiency has once again been raised.

Plant breeding is a long term process and to succeed in this context, the need for a strong and effective collaboration between public and private plant breeding entities in the Nordic countries is obvious.

This publication has presented four PPP projects active during the program period 2018 to 2020 and we have learned about several important achievements. The work within the PPP-collaboration is going in the right direction but we need to do much more in the future.

Below you find short summaries about the projects that received funding for the years 2021 to 2023.

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The new **PPP NORDFRUIT Apple project** aims at completing previous PPP efforts in apple. In this project the main focus is to carry out supplementary phenotyping, as the crop was very low due to flower frost in 2020, and more data is needed.

The project focuses on the facilitation for implementation of new technologies into the Nordic apple breeding programs. Considerable efforts have been made in tree and fruit storage diseases, however results need to be confirmed in order to capitalize the investements, and that is the main tasks of the one-year project.

The forthcoming **6P3 project** will focus on operationalization of technologies and methods developed during the previous two project phases. Phenotypic data will be combined with a plant-soil-climate model to understand interactions between genotypes, local environments, climate and management.

The aim will be to provide Nordic plant breeders with the latest UAV and imaging technologies, efficient data management tools, and a climate and stress response model to predict and breed genotypes suitable to the inevitable changing climate and environmental conditions.

The **PPP Nordic potato cultivar development project** brings three Nordic potato breeding programs and key public scientists to use available germplasm along with new tools for breeding potatoes with resistance to late blight and skin blemish diseases. The project includes four interacting research work packages along with two for management and dissemination.

Main outputs will be bred germplasm together with new methods and tools to continue improving potatoes for Nordic Europe, as well as establishing a Stakeholder Forum involving potato value chain actors who will influence the project throughout.

Spring wheat is currently cultivated at the northernmost limit for the crop where it faces several challenges linked to climate change. The **CResWheat project** aims to increase the spring wheat yield potential and self-sufficiency in the Nordic region. This requires extensive pre-breeding activities and collaboration between breeders and researchers across borders.

The project focuses on the identification of germplasm, genes, and genetic markers associated with disease resistance pre-harvest sprouting, and early maturity. Special attention will be paid to drought tolerance and diseases expected to be of future relevance to spring wheat in northern Europe.

These projects within the framework of the PPP for Pre-breeding will be implemented through the joint efforts of the Nordic plant breeding companies, the universities, NordGen and by the financing of the governments of the Nordic countries. Together we can face the future.

/The PPP-Secretariat at NordGen

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NordGen

The Nordic Genetic Resource Centre (NordGen) is the Nordic countries' gene bank and knowledge center for genetic resources. NordGen is an organisation under the Nordic Council of Minister and works with the mission of conserving and facilitating the sustainable use of genetic resources linked to food, agriculture and forestry.

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