NordGen

PPP-report
2021-2023

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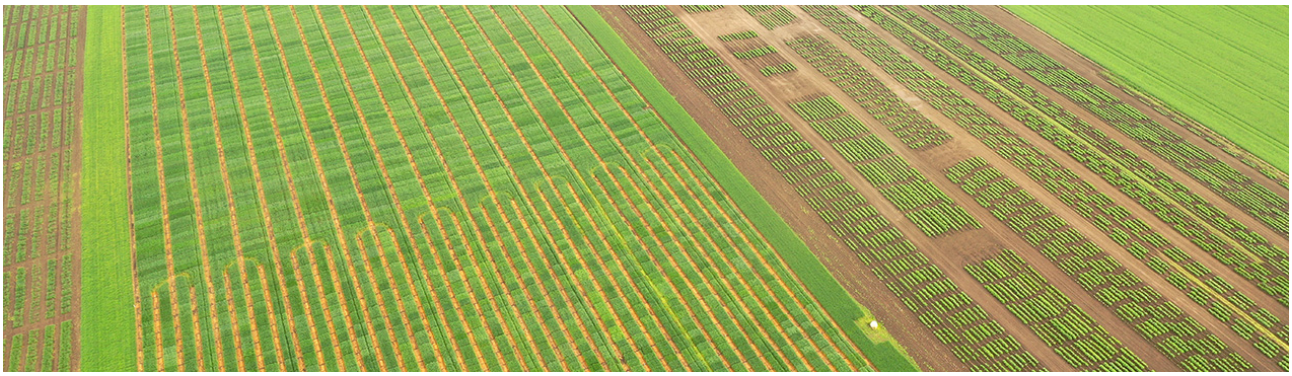

PPP Pre-breeding in the Nordic Collaboration

The Nordic region covers a widespread geographical area with a great variety in terms of environmental conditions for cultivation. Therefore, 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.

With a long and proud tradition of plant breeding, the Nordic countries have witnessed structural changes in the seed industry, leading to a reduction in Nordic breeding companies. This has resulted in a need for collaboration to develop cultivars specifically tailored to the unique Nordic market. The Public-Private Partnership (PPP) for Pre-Breeding was established to address this challenge.

In 2008, the structure of the collaboration began to form and contacts were made with all the major Nordic breeding companies. 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 primary objective of this partnership is to support long-term breeding goals for Nordic agriculture and horticulture through collaborative pre-breeding projects in a pre-competitive manner. These projects focus on developing varieties that are adapted to climate change, reduce environmental impacts, and meet new

Top photo: Graminor's field trails in Norwegian Bjørke. Photo: Graminor/Nikolai Ødegaard.

Spring wheat in field cultivation.

> *These projects focus on developing varieties that are adapted to climate change, reduce environmental impacts, and meet new consumer and market demands.*

consumer and market demands. By promoting the sustainable use of genetic resources for food production and agriculture in the Nordic region, the partnership aligns with Nordic policies on green growth and bioeconomy.

The PPP pre-breeding program focuses on projects that contribute to the development of Nordic plant breeding, farmers, and markets. These projects aim to broaden the genetic basis for plant breeding, particularly in the context of climate change adaptation and reducing environmental impacts. Additionally, introducing specific genes for disease and pest resistance, as well as other desirable qualities, is of great importance. The development of new technologies also plays a crucial role in expediting the lengthy breeding process.

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

This report compiles information about the four PPP projects which have been active during the project period 2021 to 2023 and what is expected to come in the future. The knowledge gained from these projects will contribute to a more sustainable and competitive agriculture and horticulture sector in the Nordic countries.

The Nordic PPP collaboration demonstrates the commitment to address the unique challenges of the region and the need for developing varieties that are well-suited to the demanding climate. By facilitating cooperation between public and private plant breeding entities, the PPP for Pre-Breeding is paving the way for a more resilient and prosperous agricultural future in the Nordic region.

/Birgitte Lund, Chair of the PPP Steering Committee

Nordic potato varieties.

CResWheat field trial at Lantmännen, Sweden. Photo: Therése Bengtsson.

CResWheat- Pre-breeding for Nordic Climate-Resilient Spring Wheat

Project Leader:

Therése Bengtsson, Associate Professor, Swedish University of Agricultural Sciences, Sweden.

Project Partners:

Plant breeding entities: Boreal Plant Breeding, Finland; Graminor, Norway; Lantmännen, Sweden; Nordic Seed and Sejet Plant Breeding Denmark.
Academic institutions: Aarhus University, Denmark; National Resources Institute Finland (LUKE), Finland; Norwegian University of Life Sciences (NMBU), Norway; Swedish University of Agricultural Sciences (SLU), Sweden.

Project Grants:

2021-2023: TSEK 14.536 (shared equally between the PPP and partners).

Main Goals:

- Improve spring wheat breeding programs in the Nordic countries by promoting knowledge exchange among project partners and generating new knowledge through a large-scale experiment in the Nordic region.
- Investigate the virulence structure of rust and leaf blotch populations in the Nordic region and identify potential threats from new races.
- Create a comprehensive database of genetic information and breeding tools, including genetic markers linked to resistance and desirable agronomic traits.
- Identify Nordic drought-tolerant genotypes and gain insights into the biochemical basis of their tolerance.
- Establish mapping populations for key diseases and traits essential for adaptation to the Nordic environment, facilitating backcrossing and association mapping efforts.
- Train graduate students and postdoctoral fellows.

CResWheat aims to support the breeding of climate-resilient spring wheat by identifying genetic resources for disease resistance, drought tolerance and important adaptive traits for the Nordic region, by conducting genetic studies and by making germplasm and related markers available to breeders. This goal is crucial as Nordic spring wheat production faces challenges such as a limited growing season, threats from pests and pathogens, and the impacts of climate change with more frequent periods of heavy rainfalls and drought.

To achieve this aim, we evaluated European elite spring wheat material for more than 20 traits in 24 field trials at seven locations in four Nordic countries. Donors were identified for resistance to key wheat diseases including yellow-, leaf- and stem rust, Septoria tritici blotch, powdery mildew, Stagonospora nodorum blotch, and tan spot. Additionally, donors have been identified for important traits like resistance to pre-harvest sprouting, maturity, plant height, yield components, and tolerance to early-season drought.

Strategic crosses have resulted in the development of 16 segregating populations for introgression of resistance to the diseases of focus and pre-harvest sprouting into adapted elite material. Next, genetic markers linked to these traits will be validated in the segregating populations using multi-environment trials in the Nordic countries and Estonia. This validation process is crucial to ensure the precision and reliability of the markers for effective marker-assisted selection in breeding programs.

Additionally, future efforts will include the evaluation of a collection of old landraces and cultivars from the Nordic Genetic Resource Center (NordGen) to identify sources of resistance to gout fly (*Chlorops pumilionis*), a newly re-emerged pest in Nordic spring wheat, and to introgress this trait into adapted elite germplasm.

CResWheat has fostered knowledge exchange among partners, promoting collaboration through the sharing of information, material, and field locations across diverse environments. Furthermore, the project has played a vital role in educating the next generation of plant breeders, providing hands-on experience to PhD students and postdoctoral fellows.

/Therése Bengtsson, Associate Professor, SLU

Disease nursery at LUKE, Finland. Photo: Sanna Kulmala.

Photo 3: Early-season drought stress trial (NORDrOme) conducted at IPK, Gatersleben, Germany and funded by EPPN2020, ID: 498. Photo: Kerstin Neumann.

Field visit at the Global Rust Reference Center at Flakkebjerg, Denmark. Photo: Therése Bengtsson.

Photo: 6P3 project.

6P3 – The Nordic PPP Plant Phenotyping Project – Phase 3

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; Sejet Planteforædling, Denmark; Tystoftefonden, Denmark.
Academic institutions: Agricultural University of Iceland (LBHI), Iceland; National Resources Institute Finland (LUKE), Finland; Swedish University of Agricultural Sciences (SLU), Sweden; University of Copenhagen – Department of Plant and Environmental Sciences (PLEN), Denmark.
Associate partners: Estonian Crop Research Institute, Estonia; Lithuanian Research Center for Agriculture and Forestry (LAMMC), Lithuania.

Project Grants:

2021–2023: TSEK 15.976 (shared equally between the PPP and partners).

Main Goals:

- Development of protocols for indoor and field phenotyping using various sensing systems.
- Creation of digital tools and software for managing sensor data.
- Advancement in statistical techniques and the utilization of machine learning.
- Exploration of physiological interpretations of data obtained from various sensing systems.
- Initiation of mechanistic modeling involving genotype, environment, and management interactions.

Nine years ago, the Nordic Public Private Partnership Plant Phenotyping Project (6P) was developed to amplify the application of plant phenotyping as a crop improvement tool, using emerging technologies such as UAV's (drones). Phase 1 of

the 6P project contributed to significant and quick improvements to overall output and efficiency of current breeding strategies in barley, oats, wheat, ryegrass and potatoes in the Nordic region. Phase 2 of 6P transitioned research activities into breeder's field trials. Low cost UAV technology, coupled with available light-weight broad spectrum cameras, was successfully transferred into high-throughput phenotyping. An essential part has been automation of image management and processing with algorithms developed in the software platform PlotCut3, which extracts the data and integrates it into the GIS software, QGIS. This new method of data collection, storage, and investigation is enhancing the way Nordic plant breeders can consume and interpret information from field trials.

Drone photo of an oat field.

Phase 3 of 6P advanced collaboration between partners into data driven breeding. Current development in technologies as well as a solid scientific and collaborative foundation laid in phase 1 and 2 made it possible to integrate field phenotyping methods with the mathematical plant-soil- atmosphere model DAISY. This model is designed to simulate water balance, heat balance, solute balance, and crop production in agro-ecosystems subjected to various management strategies. The model's flexible software allows for input of different management practices, soil, and weather data to demonstrate impacts on selected crop traits under different climatic and environmental conditions.

Linking high-throughput phenotyping data and the plant-soil-atmosphere model Daisy resolved in a dual model platform that allows scenario testing to identify relevant plant traits expected in challenging future growth conditions due to environmental and climate change.

In addition to research and development activities, since 2015, the 6P project has established networking activities, including an annual open symposium for colleagues from Nordic and Baltic countries interested in field phenotyping, featuring guest speakers from other countries. Additionally, there has been an annual field day hosted by the partners on a rotating basis. This has been carried out under the umbrella name of the Nordic Plant Phenotyping Network (NPPN).

Group photo captured by drone during project activities. Photo 6P3 project.

We will continue the and extend the network into NB-PPN (Nordic-Baltic Plant Phenotyping Network) to strengthen the plant phenotyping community in the Nordic-Baltic region. We do this by joining two previous networks together, NPPN and NordPlant, and continue to build on their strengths. This will be done by maintaining the annual symposia and other network activities.

/Katja Annette Willrodt, Project Manager, University of Copenhagen

SustainPotato

Project Leader:

Muath Alsheikh, Head of Research and Development/Breeder, Graminor AS.

Project Partners:

Plant breeding entities: Graminor AS, Norway; Danespo, Denmark.
Academic institutions: Norwegian Institute of Bioeconomy Research (NIBIO), Norway; Swedish University of Agricultural Sciences (SLU), Sweden.
Associate partner: Nordic Genetic Resource Center (NordGen), the Nordic countries.

Project Grants:

2021-2023: TSEK 11.828 (shared equally between the PPP and partners).

Main Goals:

- To develop and implement genetic resources and new molecular tools for effective disease resistance breeding in potato focusing on late blight and skin blemish diseases; e.g., common scab.
- The expected outcome of this project should provide Nordic breeders, researchers, retailers and growers with more competitive potato cultivars and technologies and thus increase their economic potentials.

This 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.

Project partners have agreed to contribute a total of 261 different cultivars/breeding clones that represent each breeder, with each partner providing 87 unique varieties. Additionally, 15 common cultivars have been selected to serve as checks in field trials conducted by SLU, Danespo, and Graminor. This approach will facilitate robust statistical analysis and enable data linkage

In vitro plant from the Nordic potato collection, conserved at NordGen.

across different field trial sites. All partners have finalized their 87 genotypes and agreed on the 15 common check cultivars. Historical data for these breeding clones will be collected, complementing the field trial and greenhouse test data obtained during the project. Furthermore, NordGen has contributed 46 accessions, along with their DNA and historical information.

Partners have agreed to conduct two separate field trials for the 87 breeding clones and 15 common check cultivars: one focusing on optimal yield and the other on late blight disease resistance. A unified field trial design has been developed for all trials at Danespo, SLU, and Graminor, and distributed to the partners. To ensure consistency in data collection, common protocols for assessing and scoring various traits are being established and uploaded to the Teams project page. Leaf samples from all breeding clones and check cultivars have been collected for DNA extraction and subsequent genotyping using single nucleotide polymorphisms (SNPs).

In connection with the Norwegian National project BetterPotatoBreeding, led by NIBIO (with Jahn Davik as a partner in this PPP project), a common scab-controlled experiment was initiated in 2021. This experiment involved 1710 plants (19 populations × 45 genotypes per population × 2 tubers per genotype), which were inoculated with common scab at planting time in early June 2021, with data collection in August 2021. Images were also taken for WP2 analysis. Additionally, a detached leaf assay (DLA) for assessing late blight disease on leaf discs was carried out in the greenhouse in autumn 2021. This DLA test will be repeated in 2022 and 2023.

Leaf material from all 87 cultivars and 15 check cultivars from each breeding company in the project has been sent to Graminor for preparation and subsequent SNP Chip genotyping using the SolCapV3 array Illumina 22K Chip at SGS TraitGenetics. Protocols for drone imaging in the field trials have been distributed to Danespo, SLU, and Graminor. The project will utilize drone imaging for both the yield trials and the late blight disease trials. Drone imaging and analysis were performed for the 2021 field trial organized by Danespo, which included the genotypes involved in this project, as well as for the 2021 field trials at Helgegården and Mosslunda (Skåne, Sweden), which included SLU breeding clones and a few of the check cultivars.

/Muath Alsheikh, Head of Research and Development/Breeder, Graminor AS

Graminor's field trails in Norwegian Bjørke. Photo: Graminor/Nikolai Ødegaard.

NORDFRUIT Apple – Pre-breeding for Future Challenges in Nordic Apples

Project Leader:

Dr. Stein Harald Hjeltnes, Graminor, Norway.

Project Partners:

Plant breeding entities: Graminor, Norway; LUKE, Finland; SLU, Sweden.
Academic institutions: CU-PLEN, Denmark.

Project Grants:

2021: TSEK 3.918 (shared equally between the PPP and partners).

Main Goals:

- Genetic dissection of partial resistance to European fruit tree canker by QTL mapping approach.
- Establish a breeding tool for storage rot tolerance.
- Complete phenotypic data for prioritized cultivars and characters.
- Marker validation of selected traits.

Phenotyping of field resistance, storage rot disease and phenology/fruit quality was divided in separate work packages. The phenotyping for European fruit tree canker of a ('Aroma' x 'Discovery') family along with ancestors of other offsprings of 'Aroma' and control cultivars was finalized by SLU, and several QTLs were detected. Several offsprings combining high resistance and good fruit quality were identified, and are potential parents for breeding. The developed protocol for storage rot tolerance were found too time-consuming to be utilized as a breeding tool, and initial trials with digital image analyses were conducted and seem promising. Phenotypic data for other traits recorded in the partners' field collections was carried out in order to fill gaps in previous records and shared on a common platform in Dropbox, along with other phenotypic and genotypic data.

The data was collected on a selected core collection of 50 genotypes and a diversity panel of 176 genotypes defined in the previous PPP NORDFRUIT project (2018-2020). The traits studied were full flowering, harvest date, firmness, soluble solids content, total acidity and average fruit weight. SLU shared data for 132 accessions, Luke for 44 accessions and Graminor for 30 accessions. Data from previous work on single phenol data of 214 accessions was provided by SLU and shared to the consortium. All these phenotypic data are kept by the partners and at a common platform along with SNP-data for future use. Initial studies were conducted to test on available markers, but the work related to KASP markers was delayed due to lack of respond from providers.

A DNA-marker developed from a NAC-transcription factor associated with earliness and harvest time was validated on the core- and diversity panels. It showed overall a relative strong association, which means that the results can be used for preselection of parents in programs aiming at breeding for earliness and subsequently for selection among progenies at the seedling stage in Nordic apple breeding. Validation of the markers both from European fruit tree canker and phenotyping of phenology and fruit quality traits was continued in a PhD-project (Jonas Skytte av Sätra). The common data are valuable sources for further collaboration to elaborate genome assisted apple breeding in the Nordic countries.

/Dr. Stein Harald Hjeltnes, Graminor

Development of fruit rot after inoculation with Colletotrichum acutatum. The cultivar 'Fonn' (MA992 35005 – two rows at left) is less susceptible than the control cultivar 'Aroma Husabø' (two rows at right).

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 human need. The Covid 19 pandemic, and later the war in Ukraine, has taught us not to take a functioning import and export market for granted. This development has contributed to the issue of a higher degree of self-sufficiency being higher on the Nordic governments' agenda. 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 2021 to 2023 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 will find short summaries about the projects that received funding for the years 2024 to 2026.

> *The need for a strong and effective collaboration between public and private plant breeding entities in the Nordic countries is obvious.*

One of the ongoing projects is **"CResWheat – Pre-breeding for Nordic climate-resilient spring wheat II"**, which has the main objective to support the breeding of climate-resilient spring wheat by identifying genetic resources for disease resistance, drought tolerance and important adaptive traits for the Nordic region, as well as conducting genetic studies and providing breeders with germplasm and markers.
"Having successfully identified resistance donors for seven major wheat diseases, pre-harvest sprouting, and early spring drought in the initial phase of CResWheat, we are excited about the opportunity to continue our work. Strategically utilising these donors, we established 16 populations, which we will now evaluate to identify superior progenies and genetic markers for use in marker-assisted backcrossing and selection. In the second phase, our goals include identifying donors resistant to the re-emerging wheat pest, gout fly, and the cereal cyst nematode, pests increasingly affecting spring wheat production as a result of pesticide restrictions, poor crop rotations, and climate change.
The significant advantage of public-private partnerships lies in the increased exchange of knowledge, resources and educational initiatives, which will remain an integral aspect of CResWheat." – Project Leader Therese Bengtsson, Associate Professor at the Swedish University of Agricultural Sciences (SLU).

Photo: Therese Bengtsson/SLU.

"BERRIES – Development of Germplasm for Berry Crops" is a new project with the main purpose to develop the germplasm of strawberry and raspberry available for Nordic and Baltic breeding.

"In strawberry we aim to enrich the gene pool for breeding through introduction of novel genes from the origin species of modern strawberry. In raspberry we will explore and exploit the diversity in national raspberry cultivar collections in the Nordic-Baltic countries. Garden strawberry (*Fragaria* × *ananassa*) has limited adaptive capacity due to its hybridization history. The available gene pool will be significantly enriched by introduction of additional genes and traits from the ancestor species *F. chiloensis* and *F. virginiana*. In Nordic-Baltic raspberry breeding, limited sources of resistance and restricted access to resistance markers are pressing issues. Timing of phenological stages in raspberry is crucial for adaptation to varying climate conditions and winter hardiness. By exploiting the genetic diversity within the

Nordic-Baltic raspberry gene pool, we aim to enhance the development of well-adapted and profitable raspberry cultivars for the region."

/Project Leader Dag Røen, Breeder and Project Leader at Njøs Fruit and Berry Center.

Another ongoing project, titled **"SustainPotato – PPP Collaboration to Advance Nordic Potato Variety Development with Enhanced Resistance to Diseases by Pre-breeding Phase II,"** focuses on advancing the development and utilization of genetic resources, along with deploying cutting-edge molecular and phenomic tools over the next three years.

"Our primary objective remains clear: to enhance disease resistance in potato breeding across the Nordic region, with a particular emphasis on combatting the formidable late blight disease. Notably, we are pleased to welcome METK (Estonia) as a new collaborator in this project. This partnership promises to inject fresh perspectives and expertise into our Nordic potato breeding and research collaboration. Expanding our horizons, we are set to integrate new breeding clones from the Baltic potato breeding operations at METK. This expanded pool of genetic material significantly widens our capacity to pinpoint robust genomic and phenomic tools. Over the next three years, we will investigate additional factors that hold potential for enhancing potato resistance to late blight, including the intricate relationship between potatoes and their microbiome. Our project will be structured around three interacting research work packages, underscoring our commitment to disseminating results and maintaining open communication with stakeholders throughout this project."

/Muath Alsheikh, Breeder and Head of Research and Development at Graminor AS.

In 2024, the new PPP project **"RobOat Robustness of Oats for the Nordic Region"** will also begin. This project has the main aim to develop the resistance of future oats against biotic (especially crown rust and semi-loose smut) and abiotic (drought and

waterlogging) stress factors. The partners will study the less explored oat genetic resources from NordGen and other collections by combining diverse phenotyping, genotyping and genomic methodologies.

“Breeding future oat cultivars by the smart and wide use of genetic resources is a key for sustainable solution in agriculture within climate crisis paralleled with growing demand for healthy and high-quality raw oat materials. RobOat will facilitate in ensuring sufficient supply of oats by resilient future cultivars having particularly in mind Nordic Nutrition Recommendations 2023 and the European Green Deal Strategy.”

/Project Leader Marja Jalli, Group Manager and Senior Scientist at Natural Resources Institute Finland (Luke).

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

NordGen PPP-report 2021-2023

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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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