New types of faba bean for Danish production of protein

NORFAB: Protein for the Northern hemisphere

Start date April 1\textsuperscript{st} 2016
Innovation Fund Denmark
NORFAB aims and vision

AIMS:

Increase domestic protein production

Maintain global competitiveness

Improve agricultural diversity and sustainability.
VISION:

Assemble key expertise required to develop sophisticated genome-based plant breeding methods

Provide access to germplasm with the relevant genetic diversity.

Improve the yield and quality of faba bean seeds to a level making faba bean a competitive protein crop

Cultivated on up to 10% of the arable farmland under northern European and Canadian/US northern prairie conditions.
What is special about faba bean based protein production

Plants are primary protein producers synthesizing all amino acids from inorganic nutrients

Protein production based on solar energy

Symbiotic nitrogen fixation provides the nitrogen input to faba beans

Seeds can be stored

Protein can be extracted by dry or wet fractionation

Direct on-farm use
The NORFAB team with complementary expertise

**Plant Breeders and feed suppliers:**
Nordic Seed: Ahmed Jahoor, Jens Knudsen. Phenotyping and Breeding

Sejet Plant Breeding: Birger Eriksen, Winnie Füchtbauer. Phenotyping and Breeding

DLG-Feed: Thea Dahl Villadsen. Feed value analysis

**National academic:**
Aarhus University: Jens Stougaard, Stig U. Andersen, Luc Janss, Sabine Ravnskov and Henrik Skovgaard. Genomics and quantitative genetics/genomic selection. Diseases and pests

University of Copenhagen: Fernando Geu-Flores, Svend Christensen. Biochemistry and drone observations

**International:**
University of Saskatchewan: Canada. Albert Vandenberg genetics, breeding and crop development

University of Reading: Donal O’Sullivan. Genetics

University of Helsinki: Fred Stoddard and Alan Schulman. Genetics, genomics and quality traits
Short summary, we will:

- Develop and characterize a set of 200 geno- and phenotypically diverse faba bean inbred lines.
- Produce a reference “gene-ome” of gene rich regions to underpin faba bean molecular genetics and breeding.
- Characterize trait architectures for all relevant faba bean agronomic and disease resistance traits using a novel combined association mapping approach exploiting MAGIC lines. (Multiparent Advanced Generation Inter-Cross population app 300 lines)
- Develop genomic prediction models for parent combining ability and efficient progeny selection.
- Select a subset of inbred lines as basis for future breeding of synthethic faba bean varieties.
- Provide the advanced mapping populations, mutant lines, genotyping technology and quantitative genetics methods required to build and sustain a world-leading faba bean breeding platform.
NORFAB approach to breeding
Genomic Prediction

“Parental pool” with
• Phenotypes on varieties / lines
• Phenotypes on progeny (crosses)

New cross, from same gene-pool

Prediction before collecting phenotype

Directly advance promising candidates to extensive evaluation

Add training data
Key components in breeding based on genomic prediction

Biodiversity

Phenotyping

Genome information - Genotyping

Modelling
Biodiversity in core collection

The core collection of 200 faba bean genotypes have been assembled and are under propagation.

To reduce the heterozygosity of the previous un-bred landrace material a rapid generation inbreeding scheme developed at Saskatchewan was established at Sejet Plant Breeding. New Zealand propagation under negotiation.

Parents for a Multiparent Advanced Generation Inter-Cross population (MAGIC II) were selected from this material and a cross-pollination scheme decided and initiated.
Field phenotyping.

Protocols for monitoring the most important agronomic traits (phenotypes) in place at all locations

Emergence and establishment: date, and drone imaging

Earliness (flowering): date of 80% open flowers

Ripening date: 90-95% black pods

Seed size: TGW

Basal branching: Scale 1-5

Stem breaking/lodging: Scale 0-9

Drought resistance: Helsinki

Yield

Seed protein content
WP2: Field phenotyping.

Protocols for phenotyping aphids and disease tolerance, are now in place and the first field observations using these protocols were obtained.

In parallel, drone based aerial imaging was implemented.
WP3: Screening Faba bean lines for disease and pest resistance. WP-leader Ravnskov.

To complement the field phenotype scoring of diseases NORFAB will focus on developing a pathosystem for chocolate spot caused by Ascochyta fabae. Chocolate spot is the most prominent disease

Assays for phenotyping selected lines from the core- and Magic populations for disease and aphid resistance under controlled greenhouse conditions are being developed.

Produce Botrytis fabae spores and inoculation of plants.

Inoculated and non-inoculated cv. Kontu, one week after inoculation (© Amy Sayer).

Click cages for measuring aphid multiplication
A fast mass spectroscopy methods for determining the anti-nutritional pyrimidine glucosides vicine and convicine in the many samples collected from NORFAB plant material has been tested and found to be robust.

This method is crucial for both the genetic and the biochemical approaches to elucidate the vicine and convicine biosynthetic pathway and ultimately identify faba bean cultivars with low or no vicine and convicine content.

A combined transcriptome metabolome analysis has been initiated the support elucidation of the vicine and convicine biosynthetic pathway.

Pyrimidine glycosides: ~1% of faba bean dry matter
Reduce feed intake by pigs and poultry

- A high-quality faba reference transcriptome has been completed
- This is being expanded to a pan-transcriptome using 5 additional faba accessions
- A faba gene expression atlas has been completed
- The expression atlas will be extended with a time series of botrytis responses
- Gene structures will be characterised using high accurate long reads (PacBio SEQUEL v. 6)
  - 40X coverage though joint funding
- Genotyping will be carried out using a 50k SNP chip, based on the NORFAB reference gene
  - Polymorphisms for chip design from both NORFAB RNA-seq data and INRA exome capture data
- Comprehensive database for phenotype data has been constructed this holds information on plot locations, management, phenotype descriptions and scores in a relational database structure
Hestebønner kan konkurrere med 70 hkg maltbyg

Hestebønner er et reelt alternativ til korndyrkning.

Af Lars Klausen, planteaviskonsulent og Anders Nielsen, praktikant, begge Agrovi

Is faba bean a competitive crop in Denmark?
Yield faba bean 2013 to 2018 in farmers unions trials

Mean of leading commercial varieties Boxer, Fanfare and fuego.
Dyrkningsarealet stiger

<table>
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<tr>
<th>År</th>
<th>Acres</th>
<th>Gns hkg/ha</th>
<th>Fanfare hkg/ha</th>
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<tr>
<td>2010</td>
<td>1000</td>
<td></td>
<td>40,7</td>
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<tr>
<td>2013</td>
<td>2646</td>
<td>41,5</td>
<td>44,6</td>
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<tr>
<td>2014</td>
<td>4120</td>
<td>48,98</td>
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<td>14800</td>
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<tr>
<td>2018</td>
<td>24823</td>
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Sådan opnår du en høj dyrkningssikkerhed i hestebønner

Planteavlskonsulent Anders Smedemand Musse - Sønderjysk Landboforening
Arealet udvides fordi......

• Forædling af nye sorter
  – højere udbytter
  – tidligere høst

• Ændret dyrkningspraksis

• Flere hjemmeblandere ser fordel i at kunne dyrke deres eget protein

• Fantastisk forfrugtsværdi
  – Ukrudtssanerende (græsukrudt)
  – Sygdomssanerende
  – Mere kvælstof og liv til jorden
Future perspectives:

Protein quality f.ex higher methionine and cysteine content

Protein fractions for food

Protein for specialized food and feed

Reduced vicine and convicine content, cause favism in people with a genetically inherited glucose-6-phosphate dehydrogenase (G6PD) deficiency, app 400 mio affected.
Stig U. Andersen coordinates ERA-NET SusCrop project “ProFaba”: Developing improved *Vicia faba* breeding practices and varieties to drive domestic protein production in the European Union.

Fred Stoddard coordinates ERA-NET SusCrop project “Legume-Gap”: Increasing productivity and sustainability of European protein production by closing the grain legume yield gap.
Thanks for your attention
### Balance in Danish protein feed supply 2015

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<th>total</th>
<th>Danish</th>
<th>Import</th>
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<tr>
<td></td>
<td>mio. kg</td>
<td>pct.</td>
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<tr>
<td><strong>Feed consumption total</strong></td>
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<tr>
<td>Cereals</td>
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<td>Protein supplements</td>
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<td>Oil cake</td>
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Danmarks Statistik, feb 2016