# LegumeGap

## Increasing productivity and sustainability of European plant protein production by closing the grain legume yield gap

Fred Stoddard, University of Helsinki

Total budget 1.8 M €

EUROPEAN RESEARCH AREA ON SUSTAINABLE CROP PRODUCTION

The ERA-Net Cofund SusCrop is funded by European Union's Horizon 2020 research and innovation programme under grant agreement No 771134

# Background rationale

- Protein self-sufficiency
- Crop diversification
- Reduction in fertilizer and pesticide use
- Reduction in GHG emissions
- Sustainable diets
- Prevention of land degradation and biodiversity loss

Soy meal arrives at Dutch factory

Roots with nodules

Faba bean crop in Finland

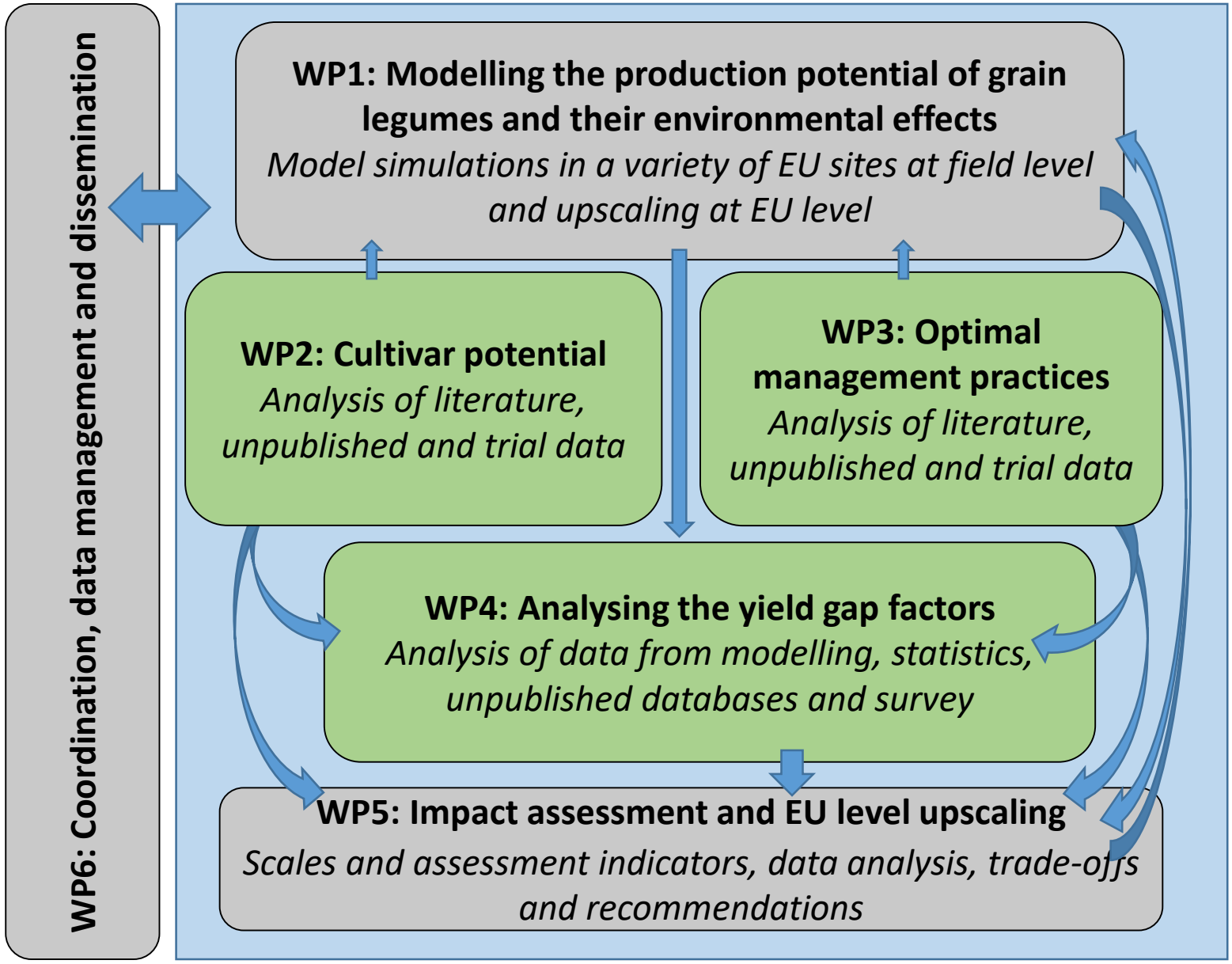
# Plant protein is needed!

- Legumes can produce protein with minimal usage of N fertilizer (synthetic or manure)
- Many options available
- We focus on:
- Soybean for warm-temperate regions
  - 39% protein, familiar in food and feed industries
- Faba bean for cool-temperate regions
  - 29% protein, does not affect those with soy allergy

# Europe could grow more, but…

- Some problems we can't solve
  - Promises to import *more* soy from USA (trade war threats) and South America (new trade deal)
- Some we can
  - Farmer reluctance to grow legumes
  - Industry reluctance to use local legumes
- How we will influence it:

# Structure and objectives




**Project test cases**

**North-eastern** (Finland , Latvia), **North-western** (Scotland, the Netherlands), **Central** (Germany, Poland), **Southern** (France, Spain), whole **EU**

# Exciting new aspects

- Quantifying the “knowledge” component of the yield gap (WP4)
  - Novices don’t succeed first time: how big is this yield gap?
  - How can this knowledge gap be reduced? Survey farmer knowledge.
- Quantifying trade-offs (WP5)
  - Protein self-sufficiency, $N_2O$ emission, cereal replacement, social & economic sustainability
  - Mapping these with other data to highlight potential production zones
  - Thus multi-disciplinary!

FACCEJPI
SusCrop
ERA-NET

# Consortium members

UNIVERSITY OF HELSINKI
FACULTY OF AGRICULTURE AND FORESTRY

Latvia University of Life Sciences and Technologies

Universitat de Lleida

Wrocław University of Science and Technology

SusCrop ERA-NET

# Progress to date: WP1 on crop model

- Excellent progress on improving the plant-growth model STICS for soya bean using available datasets
- Less progress for faba bean since fewer datasets available, more data to be supplied soon
- A leading group in Wageningen has joined the consortium as an unpaid member

FACCEJPI
SusCrop
ERA-NET

# WP2 on cultivars

- ZALF hired a PhD student to compile European data on faba and soy cultivars, yield data, phenology
- Field experiments on faba (3 cvs) and soy (10 cvs) in 3 sites x 3 countries in 2019, ~8 sites expected in 2020

# WP3 on management practices

- UH is compiling review on management practices for faba, ZALF for soy
- Scientific literature well in hand, unpublished national-level data much less so
- Deliverable in 3 months
- Experiments on water management, timing of sowing, weed control in progress in DE and ES

# WP4 on yield gap *analysis*

- Dissecting the yield gap into its components
  - Data coming from WP2, WP3 and the survey
- Farmer survey
  - What do farmers know? We propose that the knowledge gap is a large part of the yield gap
  - Implementing took far longer than expected: kicked off late March instead of early February
  - SLU now an unpaid partner for conducting survey
  - More advertisement needed in all 8 countries
  - https://www.surveygizmo.eu/s3/90220084/Default and choose your language

# WP5 on scale-up

- Mapping suitable areas for the two crops across Europe, including areas subject to key stresses
- The Wageningen group does related work, cooperates here
- H2020 project LegValue has done some mapping of suitability for soy, has promised to share it
- Testing the best current crop to displace with the legumes

# WP6 on management & communication

- Procedures in place to ensure data transparency and availability after the project
- Website under construction
- Corona has disrupted plans for the annual meeting and some fieldwork is at risk
- First-year meeting in Berlin postponed from June to September, followed by PhD student workshop @ ZALF
- Plenty of dissemination planned (next slide)
- Possible conference travel to European Society for Agronomy conference, Seville, early September (if…)

# Outreach methods include…

- Participation in on-farm field days and other public events
- Downloadable brochures & other documents on optimum production methods in national languages
  - Links with Legumes Translated
- Improved functionality and accessibility of rotation-planning tools
  - Links with Leg4Life
- Information push through social media and scientific channels
- Farmer survey

# Conclusions

- LegumeGap, Legumes Translated and Leg4Life have complementary components
  - Developing and merging data for planning rotations
  - Communicating with farmers about various aspects of legumes
  - National depth and international breadth
- UH hired Kiflemariam Belachew as postdoc, 50% ProFaba and 50% LegumeGap
  - Leaves some budget for summer workers

FACCEJPI
SusCrop
ERA-NET

FACCEJPI
SusCrop
ERA-NET

# PROFABA

## Developing improved *Vicia faba* breeding practices and varieties to drive domestic protein production in the European Union

Total budget 2.35 M €

EUROPEAN RESEARCH AREA ON SUSTAINABLE CROP PRODUCTION

The ERA-Net Cofund SusCrop is funded by European Union's Horizon 2020 research and innovation programme under grant agreement No 771134

PROFABA

# Objectives and perspectives

- Make faba bean an economically competitive and attractive crop for European farmers
- Promote a more balanced and protein-self-sufficient European agricultural system
  - which takes full advantage of biological nitrogen fixation
- By developing genomic tools to assist accelerated breeding

FACCEJPI
SusCrop
ERA-NET

# The ProFaba consortium

Nadim Tayeh & Gregoire Aubert
bruchid tolerance

Wolfgang link
frost tolerance

Olaf Sass
breeder

Francoise Labalette
breeder

*Coordinator: Stig U. Andersen*
rhizobium interactions
web portal for data sharing

Winnie Füchtbauer
breeder

Fred Stoddard & Alan Schulman
acid tolerance
genomics

Ana M. Torres
disease & autofertility

Ignacio Solis
breeder

Sheila Alves
protein quality

Donal O'Sullivan
protein quality
genotyping

# The ProFaba consortium

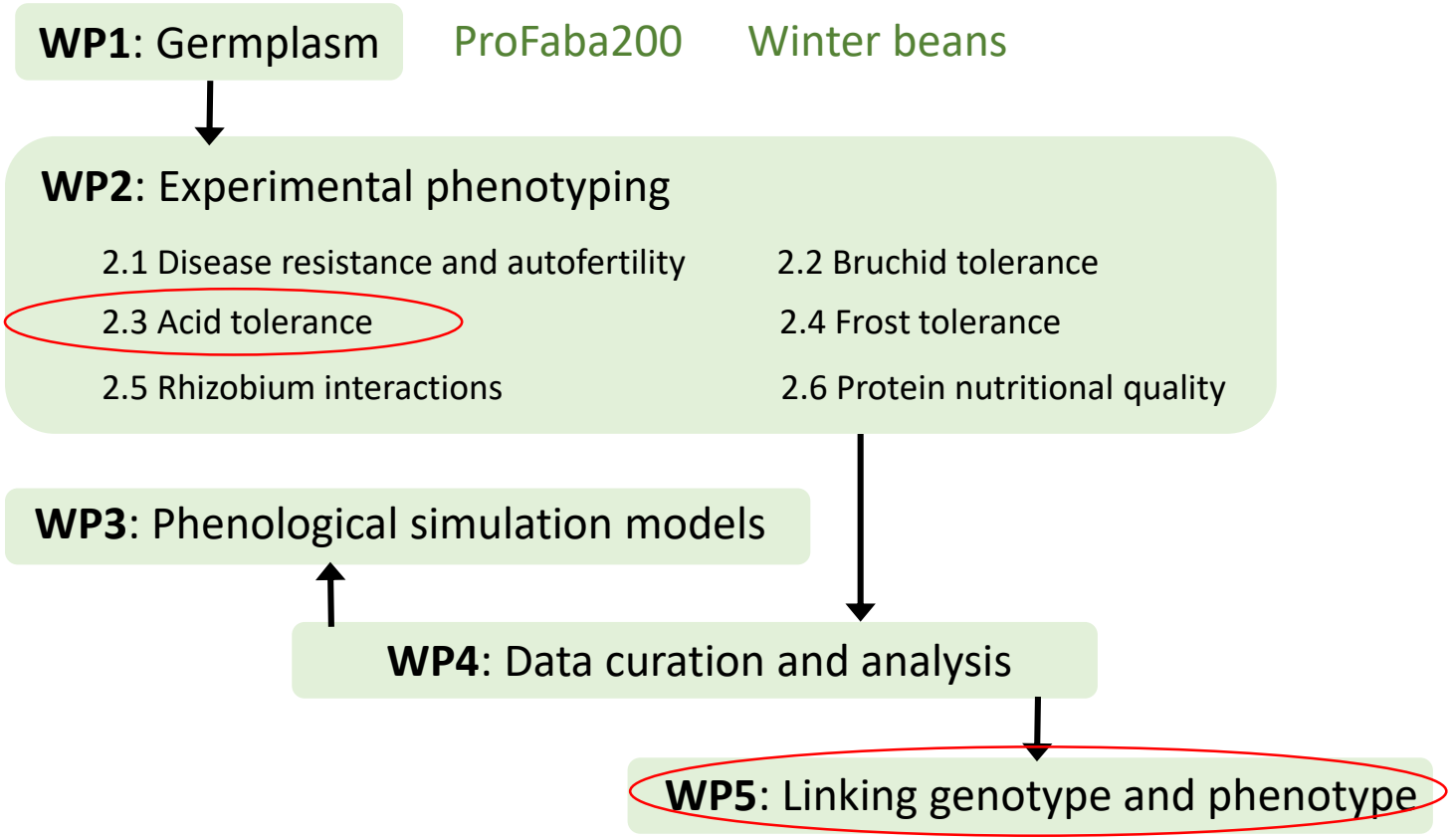

FACCEJPI
SusCrop
ERA-NET

# Interacting projects

- Norfab: Danish Innovation Fund to Aarhus Uni, Sejet Plant Breeding and Nordic Seed with UH, U Reading and U Saskatoon
  - (Genomic) tools to accelerate faba bean breeding
- Papugeno: Academy of Finland to me at UH
  - Sequencing the gene space of faba bean, with Alan Schulman
- Also genotyping and phenotyping projects at U Reading and U Saskatchewan
- H2020 EUCLEG

FACCEJPI
SusCrop
ERA-NET

# Project structure

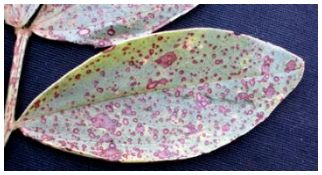


# Project structure

**WP2**: Experimental phenotyping

- 2.1 Disease resistance and autofertility
- 2.2 Bruchid tolerance
- 2.3 Acid tolerance
- 2.4 Frost tolerance
- 2.5 Rhizobium interactions
- 2.6 Protein nutritional quality

2.1



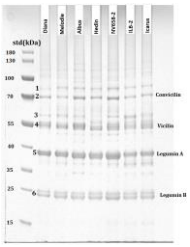
2.2

2.3

2.4

2.5

2.6



# Progress to date: WP1 on germplasm

- > 200 lines chosen
  - Some overlap with Norfab project
- Multiplication of germplasm at several nodes
  - UH did 10 lines
- Distributed by Univ Göttingen for phenotyping

FACCEJPI
SusCrop
ERA-NET

# WP2 on phenotyping

- UH has responsibility for rootzone acidity
- Aquaponic method: 4 treatments of 4 seeds of all 200 accessions
  - pH 7, pH 4.5, pH 4.5 + 82 µM $Al^{3+}$, same + 2 days recovery
  - 3 sequential reps:
    Good reproducibility
  - 3 accessions with outstanding resilience = recovery
  - Data still being analysed

# To do on this task

- ~10 each low tolerance, average tolerance, high tolerance
- Run experiment in pots, follow plants through later growth stages
- RNA of stress responses
- Data into Genome-Wide Association Study GWAS of whole project
  - Identifies chromosome regions associated with response

# WP3 on phenological modelling

- Cooperation with LegumeGap, focus different
- Good datasets on climate needed from partners

FACCEJPI
SusCrop
ERA-NET

# Other WPs

WP4 on data management

- Transparency is key
- Partners to prepare data for database

WP5 linking genotype and phenotype

- Has not started yet
- UH leads this WP

WP6 on dissemination and communication

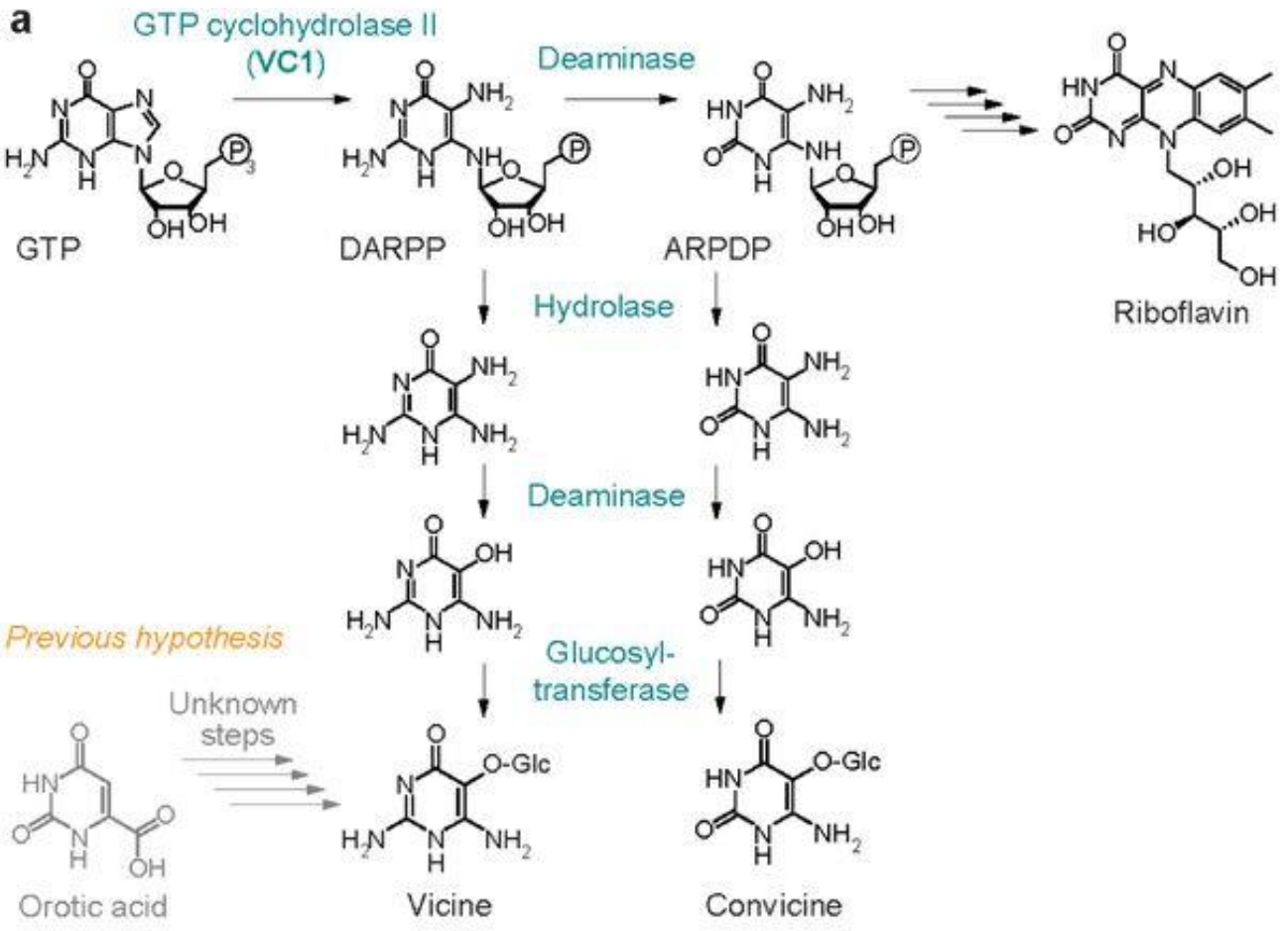
# Major progress on vicine-convicine

- The two compounds that limit use in feed and, for some people, food
- “Low” gene known for 30 years, reduces V-C by 90-95%, now called VC1
- Norfab / Papugeno / Profaba teams have analysed the gene
- Preprint on BioRxiv

FACCEJPI
SusCrop
ERA-NET

# New biosynthetic pathway for V-C

- VC1 is altered in low-V-C genotypes



# Benefits of structure of both projects

- Multi-site testing – genotype by environment interactions – across a wide range of environments
- Independent partner budgets
- Critical mass of faba bean knowhow (and soybean in LegumeGap)
- Sharing of germplasm, data, and analysis methods
- Integration with related projects

FACCEJPI
SusCrop
ERA-NET

# Stakeholders and end-users

- Breeders
- Farmers
- Agricultural advisors
- Farm supply companies
- Grain merchants
- Inoculum producers
- Producers of protein-based feeds and food
- Consumers
- Politicians

FACCEJPI
SusCrop
ERA-NET

# Conclusions

- Faba has a very large genome (13 Gbp)
- ~1% is gene space
- Technology has only recently advanced to allow sequencing of such a large genome
- Several complementary projects use different genotyping tools, assess different phenotypes
- Key European groups involved, talking with Canadian and Australian counterparts: good prospects for continued collaboration rather than competition

FACCEJPI
SusCrop
ERA-NET