Thesis Part 1

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# Part One

SBPA = Swedish Breeding Program Accessions

SBP = Swedish Breeding Program

CCA = Core Collection Accessions.

NWE = Northwest Europe

## Introduction

**purpose** draft 2

Soybean, belonging to the Fabaceae family and scientifically known as *Glycine max* (L. Merrill), is globally recognized as the primary grain legume crop due to its high protein and oil content. However, its genetic diversity has decreased over time due to domestication and artificial selection [@hyten06], [@gizlice96].

It is the purpose of this review to present the relevant knowledge and research about Soybean in northwest Europe as well as to motivate de novo expansion of the cultivation range of Soybean to north-western Europe. And to review that which is relevant to the expansion of the cultivation range and to collect the historical and now relevant soybean endeavours stored in the historical literature and the NordGen seed banks.

**Why it is Important: low diversity** draft 1

According to [@gizlice96] only 19 landraces are thought to have contributed as much as 85% of the genes to the North American breeding pools retaining 72% of genome diversity and being furthermore imposed by selective breeding, 79% of rare alleles were lost [@hyten06].

Adaptation of crops to expand cultivation ranges.

This reduced level of genetic variation in elite breeding populations means that in the case of soybean, there is a need to look elsewhere to increase germplasm utilization for abiotic adaptation. Relevant accessions to have the potential for abiotic adaptation to cold tolerance for a rapidly changing climate have been identified… [@haupt20].

**the answer** draft 1

But also, recently, Swedish accessions that are stored in the NordGen gene bank have been revealed to originate from a breeding program with the intermediary and the resulting cultivars of a Swedish breeding program that ran during the 1840s to the 1970s which used material consisting of a mixture of elite cultivars and Japanese landraces.

(Should this be at the very end instead and with more detail, or here and at the end with more detail?)

It would be intriguing to delve deeper into these Swedish accessions, their diversity, and how they are connected to the remaining germplasm. Is it possible that there is a detectable bottleneck from the founder population to the breeding population and that the breeding program itself created a bottleneck, the effects of this seen as is increased drift and decline in genetic diversity.

Recent research has shown (ref.) that a lot of the breeding programs up until the development of marker selection (ref) has had a lot of the results simply due to drift than actual selective breeding or genetic selection (ref). What more do I want to say here?

**Why the subject is timely** draft 2

The demand of soybean production only increases and has even more than doubled since the year 2000 to 2020 [@fao23]. An example of this is the report from the Sustainable Development Goals (SDG) of the United Nations, goals where it is stated that x much more soy for human protein consumption will be needed to reach the SDG goal number 2 of Zero Hunger. *Glycine max* is the domesticated species of *Glycine soya* that originated in China and was domesticated to *Glycine max* around 6000–9000 years ago around 23°N and 49°N [@carter04], [@kim2012b].

**why soybean is relevant: because it’s an important crop** draft 2

Soybean is a crop of global economic importance. It is successfully grown (where) latitudes. in north and south America for feed and is imported to Europe in great amounts (4/5ths?) (ref) for animal feed. Soy is the perfect feed crop because of its protein and oil content. More than three quarters of that produced is fed to animals. It is also gaining popularity to enough protein in a vegetarian diet (20% of produced amount).

**there are downsides of the status quo** draft 1

There are things to consider when it comes to growing Europe’s animal feed on the other side of the earth. Transport. Deforestation. (1/5th of deforestation is due to cropland expansion by crops like soy and oil palm (ref)).

On top of the interest in the breeding of higher protein rich crops here in Europe, as can be seen with the re-emergent interest in other nitrogen fixing crops such as Faba Bean (Vicia faba) or other legumes, growing soybean in NWE North-western Europe could be a logical addition to the crop rotation.

The instability of energy resources in Europe due to war has rekindled the idea of self-sustainability as an important political agenda. It seems that Europe, for these socioeconomic and environmental purposes, will be more self-sufficient in the future when it comes to resources including plant proteins and fats sourcing. We import soy and other crops mainly as feed to our animals that then go on to be a source of meat protein for human consumption.

**The idea to develop soybean as a crop in northwest Europe** draft 1

The idea is that it could be a good idea to research the possibility of developing elite cultivars that would grow well in North-western Europe. Review what we know and to investigate and research the interesting (Swedish) and compare (CCA+GRIN) accessions that we already know of.

**what to review:** draft 1

Soy domestication and the Detection of selection signatures in genes of interest relevant to the crop in general and abiotic adaptation. The state of soybean agronomy and what are the climate change considerations for the future. Population genetics can show relations and genetic diversity underlining the need for new genetic resources in the breeding pool. abiotic adaptations needed and climate change considerations. The traits we know have an importance in northern Europe.

## Soy domestication and botany 500 [] draft1

**general introduction to soybean in a botanic sense draft1**

Soybean is an annual short-day plant, meaning it will start to flower when the day length gets shorter and reaches a critical point. This Photoperiod sensitivity gives soybean a natural distribution range to the high latitudes.

what more botanical is basis important here?

Autogamous. *Glycine max* 2n=40 chromosome the genus and polyploidy interesting in speciation or becoming the genus glycine.

*Glycine max*

Kingdom: Plantae

Phylum: Magnoliophyta

Class: Magnoliopsida Order:

Fabales Family: Fabaceae

Subfamily: Faboideae

Genus: Glycine

Species: G. max

Botanical name: Glycine max (L. Merr.)

Common name: Soybean, Soya bean

**domestication time and place draft1**

Wild soybean grows commonly in eastern China (from 24–53°N lat.), Japan, Korea, and the eastern extremes of Russia [@carter04].

Traces of the cultivated soybean *Glycine max* in the literature have been found in The Chou Dynasty (1122–221 BC) of China. And as the Dynasty expanded with trade, soybeans migrated with people to South China, Korea, Japan, and Southeast Asia [@hymowitz1970]. However, for soybean to already be a trade commodity at that point the domestication process must have taken place well before. Modern cultivated soybean *Glycine max* is estimated to have been domesticated from wild soybean (*Glycine soja* Sieb. & Zucc.) in East Asia 6000–9000 yr. ago [@carter04], [@kim2012b].

**Origin hypotheses (draft 1)**

It is still a debated as to whether *Glycine max* or originates solely from *Glycine soy* as the single origin hypothesis [@sedivy17]. The other two debated hypotheses are the multiple origin (this is this and that) and the Complex origin of soybean considers that *Glycine max* and an intermediate *Glycine gracialis* formed a complex eventually to become domesticised to *Glycine max* [@lee11], [@kim2012b].

origin hypothesis adapted from [@sedivy17]

## Soy botany

## Soy biotic and abiotic adaptations or difficulties in relation to growing in higher latitudes.

## Climate change

**plant stages as defined in V1-V? R1-R8**

The V stages are defined by the number of trifoliate leaves that have developed (unrolled) on the main stem, not the branches. VE Stage: Emergence VC Stage: Cotyledon V1 - V3 Stages: First, Second & Third Trifoliate V4 Stage: Fourth Trifoliolate. branching beginning V5 Stage: Fifth Trifoliate. About a week until flowering begins

R1: Beginning bloom. At least one flower appears always on the third to sixth node on the main stem. The plant is at the V7 to V10 stage.

R2: Full Flowering R3: Beginning Pod Development R4: Full Pod R5: Beginning Seed R6: Full Seed R7: Beginning Maturity R8: Full Maturity

**MG** draft 2

There is a broad variation in sensitivity to photoperiod in soybean cultivars. The maturity group (MG) system is widely used to group soybean varieties based on their growth periods and photothermal responses, categorised based on their growth periods and photothermal responses. Although, there is no universal standard or quantifiable methodology for (MG) classification (also referred to as Maturity Group Reference (MGR)). There are 13 MGs ranging from MG 000 for the very early maturing varieties to MG X for the latest-maturing varieties, with a possible extension of this range coming since MG 0000 varieties have been described and are used in more recent papers classifying maturity groups [@song19], [@jia14].

**biotic and abiotic adaptations**

What decides the range what adaption need to be done

What is photosensitivity? when flowering occurs. weeks after flowering.

what does temperature mean? for flowering?

maturity. time to maturity in weeks

The wild type is photoperiod sensitive E1 allele.

reproduction can also be taken into consideration.

**traits where soy is or is not adapted to or relevant to NWE climate**

days to flower are also dependent on accumulated temperature. (ref)

cultivars/genotypes/phenotypes? differ in photoperiod requirements for flowering.

for a rapidly changing climate, or de novo adaptation of crops to expand cultivation ranges. selection of suitable germplasm with phenotypic data to increase germplasm utilisation [@haupt20]

**The change in climate as seen in the CCA paper or other climate consideration papers for future European crops in general?**

Our climate is changing, what does this mean for a crop like soy? how does the changes in our climate and the future changes need to be taken into consideration?

## Soy agronomy/economy draft1

we should grow soybean in NWE Because:

**composition**

the protein composition is unique and there is a high oil content in soybean.

**climate change** draft 1

*Glycine max* is a short-day plant of the family *Fabaceae* also known as a Legume; it is one of the plant families that has a symbiosis with bacteria in nodes in the roots which fixate Nitrogen. Making soybean a unique crop because, as other legumes, it has high protein content. But uniquely from other domesticated protein rich crops, there doesn’t follow along a lot of carbohydrates in the seed. This makes soybean a fitting protein source, the protein content 30-45% protein and quality make it the most prevalent and cheap source of protein [@messina22], [@fang22]. and 15-25% oil

**why good idea food security** less international dependency:  draft 2

Compared to plant-based foods, the environmental and climate impacts of meat production are significantly greater. This is because meat production generates a higher amount of emissions per unit of energy due to energy losses that occur at each trophic level.

340 million tonnes of soybean were harvested in the market year 2019/20.

0,2% of that amount was produced in Europe itself and 29,8% of the total produced amount was imported into Europe (eu27+UK)(ref. USDA numbers).

Soybean is a great source of vegetarian soybean for direct or processed human consumption. According to [@messina22], soy-based meat substitutes compared with their animal-based counterparts. Because of the large acreage devoted to growing soybeans, soybeans possess enormous potential for fulfilling the escalating global population's caloric and protein requirements. Soy is also a vital ingredient (soy lecithin) in many processed foods. (Numbers, ref)

**Is there a need for more detail on how big soy is in the world? A lot of the actual introduction part should be moved to here… draft 1**

Soybean is the main source of plant protein and oil in the world, worldwide production in 2020 was 353.46 million tons. In The European Union in the same year 2.69 million tons were produced, and only 2560 tonnes in Northern Europe [@fao23]. One fifth of the soybean produced is used for human consumption. The oil is the main source for cooking oil in the world and the [@fang22]

**important crop due to all the uses. food feed, the production of biofuels, bioplastics, and other industrial products. Draft 1**

protein quality [@gorissen18] 30-45% protein and 15-25% oil

field trial in dk 2009 “It is possible to grow soybeans in Denmark, but under conventional cultivation conditions production could hardly compete with imports roasted soybeans. As a niche production, a yield of around 20 hkg/ha Danish-bred, organic soybeans might be profitable, especially when sold for consumption. Important cultivation aspects are early establishment of varieties that flower and ripen early as well as the development of methods for harvesting, cleaning, and drying off the seeds.” [@petersen09] In similar field trials conducted in 2010 included several of the Swedish accessions, where the yield for Fiskeby V was only 11.2hkg/ha. [@petersen10]

**transition paragraph**

These traits affect the distribution of soybean as a crop. can soybean grow in Europe? [@kurasch17], [@petersen10]

**Are there similar places (where soy is grown? Canada Japan. why not just adapt their cultivars? how are they different. More about cultivar choice in agriculture?**

see chapter from book ordered Soybean: botany, production and uses.

for the north the ability to reach full maturity is the problem? what do the different papers say.

**crop rotation and nitrogen fixation *mention here or somewhere***

Soybean as a legume is vital for crop rotation, not only because it is a good crop to have before a grain, but if it is also a cash crop, then even better.

## Soybean pop gen 500 [] draft1

**transition paragraph? what’s happened after the domestication. short history in two sentences.**

Several severe genetic bottlenecks occurred during soybean domestication. During domestication to the landraces the sequence diversity in comparison to the wild species was halved, with 81% of rare alleles lost [@hyten06] and two major bottlenecks when very few landraces were used in the development of the north American modern cultivars and then on to the breeding of the past 75 years in America to the elite cultivars there is now.

\*\*\*\*Fst\*\*\*\* **genetic bottlenecks**

the Fst paper talking about the bottlenecks showing how soy diversity has further been diminished.

**genetic architecture of soybeans**

see pan genome paper

frameshifts, snps, indels, cnvs, LD fst?

**Population structures like clusters**

inferred population histories and demography’s

**diversity** Diversity pools. what is this and where is there diversity then?

**selection or deleterious mutations removed, and diversification occurred**

selection signatures

**genes** **underlying domestication-related traits (DRT) /improvements /diversification** photoperiodic flowering flower, seed coat and pod colour

see [@sedivy17]

## Soy gene banks 500 [] draft1

**transition paragraph**

the mentioned diversity pools are kept as gene banks!

**Extremely short history of gene / seed banks and their paramount importance!**

“The largest collection for *G. max* is maintained at the Institute of Crop Germplasm Resources in China which has over 23,000 accessions while the second largest collection is maintained at the USDA Soybean Germplasm collection in Urbana, IL, USA which contains over 18,000 accessions (Carter et al., 2004).” from book: https://www.sciencedirect.com/science/article/pii/B9780983079101500078

**and soybase?**

**GRIN / USDA Soybean Germplasm collection**

**NORDGEN gene bank**

Although there is worldwide

## Soy history in NWE (SBP) + CCA 700-900 [] draft1

**Transition paragraph?**

**SBP origin** draft 2

Together three sources, a paper called *Soybeans for cool temperate climates* by Sven A. Holmberg, published in 1973 presents the results of a soybean breeding program from 1939 to 1973, With two books, one about everything soybean in northwest Europe and the other about plant breeding in Sweden it is possible to piece together the story of the genetic source of soybean from the Nordgen gene bank. Three cultivars were the result of the program Fiskeby V being the highest yielding and the tallest with, Bråvalla and Träff which are short and extremely early varieties, ripening 8 and 12 days earlier than Fiskeby V. Before the soybean breeding program in Fiskeby, several attempts were made with varieties mainly from Canada and Germany but didn’t succeed, so in 1939-40, Sven A. Holmberg made a journey to sample collections in northern Japan and Sakhalin, Eastern Siberia. Locations were chosen, due to a summer climate like that of Sweden, and a long tradition of breeding soybeans. consisted of crossings between early, hardy, and low-growing varieties from these parts, and higher-growing varieties, mainly from Germany (with its origin in Manchuria). There are primarily three characteristics that distinguish the soybean varieties from Holmberg’s breeding and are entirely essential to the adaptation to the Swedish climate: (1) Adaptation to long-day climate. (2) Tolerance against low summer temperatures. (3) Early ripening.

Unfortunately, even with the new Swedish varieties, Soybean yield was too unpredictable and too low to become a crop grown in Sweden, at the time. To this day, the soybean varieties from Fiskeby are well known among soybean growers worldwide, consisting of a source for early gestation and tolerance against low temperatures in breeding programs, wherever these characteristics could be incorporated.

**CCA draft** 1

General introduction to what the CCA is and the considerations around making it.

Environmental data characterising the geographic origin of germplasm in combination with environmental conditions of the Target Population of Environments. genes that are known or hypothesised to be involved in abiotic adaptation. [@haupt20]

## Conclusion and perspective (questions & possibilities) 350-500 words [] draft1

**what we don’t know draft 1**

In this case, the problem is to determine whether the 136 soybeans in the NORDGEN gene bank could be of use, given the goal of growing more protein and oil rich crops in Northern Europe. It is important to address this question because it could lead to the development of a breeding program for a future crop in the region.

However, there are gaps in knowledge that need to be addressed. Firstly, it is unclear what exactly is contained within the NORDGEN accessions and how they relate genetically to the rest of the soy. Furthermore, it is uncertain whether there is any genetic potential or a good starting point for future breeding programs.

Although there are some known factors, such as the cultivar Fiskeby and a few other accessions that are thought to have potential, it is important to establish whether the founders were indeed the founders and whether the Swedish accessions are a genetic unit. Additionally, it is not clear if the selection of founders and succeeding breeding program selected for desirable traits or if it was simply a result of drift.

While there are areas of interest in the soybean genome, such as flowering and cold tolerance, it is necessary to look for diversity and signals of selection there. It is also important to understand how the CCA relates to the SBPA, and once these questions are answered, we can better understand how to proceed with optimal breeding for soybeans in Northern and Western Europe.

In conclusion, the diversity within soybeans is low, and the core collection is still too large to begin a breeding program. Additionally, the parameters, which are only weather and origin in comparison, are too few and phenotype data should be looked further into to narrow down the potential accessions. However, the CCA provides a starting point, and there is potential within the NORDGEN accessions that could be added to this group making an even better potential which can be developed with further study and research.

\*Also see [@dottinger23] for great reasons for why we need to breed for regional adaptation in soybean.

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! how to reference this website in a way they want via Zotero? [@fao23] “FAO. Crops and livestock products. Licence: CC BY-NC-SA 3.0 IGO. Extracted from: https://www.fao.org/faostat/en/#data/QCL. Date of Access: 06-02-2023.”

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