Legume Generation

Boosting innovation in breeding for the next generation of legume crops for Europe

The plan for boosting the breeding of lupin

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Legume Generation Report 2

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Contents

The lupin scene

There are two large areas of lupin production in Europe: One in Poland with about 100,000 ha. The second one is in north-eastern Germany with about 25,000 ha of lupin production. In both areas most of the lupin grains are used for animal feed in the farms where the grains are produced. That means that there is no 'free' material available for the feed industry. Most production for food applications in Europe is done on a contract production basis, but still at a low level. The variety types that are used are exclusively sweet forms of narrow leafed, white and yellow lupins.

The breeders

We have analysed the OECD (Organisation for Economic Co-operation and Development) list of eligible varieties for seed certification and made out several distributeurs of lupin varieties but only a few European breeding programmes where the varieties come from – in Poland and in Germany. As far as we are aware, there are only limited breeding activities of white lupin in France. In the Mediterranean countries we did not find original breeding programmes with regular output of varieties. We know that there are breeding programmes in Belorussia and Russia, however, due to the actual political situation we are not able to make contacts to those programmes.

Who we are and our ambitions

Our lupin innovation community deals with three different species: *L. albus, L. angustifolius* and *L. mutabilis* (white, narrow-leafed, and Andean lupins respectively). The plant material of these three species has different levels of germplasm development and hence, different strategies to follow and different expectations to fulfil in terms of cultivar development level. Different species might find their opportunities in different geographic regions and/or for different purposes (food, feed, technical purposes).
Figure 2 shows how the lupin IC is integrated in the Legume Generation project and how we follow the way from science to growers.

We believe that globally there is no real further progress in lupin breeding to be expected within the **genetically very narrow genepool of sweet lupins**. That is the reason why we focus on bitter lupins and their characters. There are large collections of bitter types in the genebanks which have to be described and used in pre-breeding and breeding programmes. Our innovation community (IC, see The Lupin Innovation Community) partners already work with different collections of genebank-accessions with different goals and different main topics in European (e.g., INCREASE) or national projects (LupiZAV, LupiBreed, Luprome, Luprocess, LupiRhiz) – not always with the goal to develop cultivars. Hence, we want to exploit the outcome of these different approaches and combine the results via exchange of plant material and crosses of material from the (pre-breeding) research with elite lines from our breeding programmes and with state of the art varieties from the market.

Our goal in narrow leafed lupins is '40/40', that means 40 dt/ha grain yield and 40% protein content. The genetic potential is there, we have to make better use of it through improved resource capture by the crop.

In white lupins, we focus on grain yield, anthracnose tolerance and alkaloid content. We have first results in bitter genetic resources that hint a higher yield potential compared to actual sweet varieties.

With Andean lupins, our main approach is seed multiplication under European conditions with some selection for grain yield, alkaloid content and nutritional features. Andean lupins have a very long development phase. Winter survival of this species might play an important role in its development in Europe.

The Lupin Innovation Community

The Lupin Innovation Community (LUPIC) is a group of 19 partners from 15 organisations (Table 1). ESKUSA is the only breeding company in this group (further breeders are welcome). We are actively seeking companies to get involved in increasing lupin cropping area. We have an ongoing breeding programme in narrow leafed lupin and a young programme in white lupin. In both species, we are dealing with alkaloid-rich forms, however, we are aiming at the feed- and food-market with sweet lupins. We work together with a food-technologist who is able to process food-grade protein from bitter grains (Lupino AG) and we try to find technical applications of lupin protein in films or glues. This is to immediately make use of the bitter forms.

A group of researchers that develop genetic, analytic and other tools, plant material and basic information in different lupin species (JKI, IPG, UPM) supports the breeding programme with plant material, new traits and even a new species for the European market – the Andean lupin. Another group of researchers offer techniques to analyse certain characters (IPK, RU, BOKU). Two partners offer very informative field testing locations with different main observation topics (ABER, IHU). According to the project structure, the whole LUPIC-group profits from and interacts with the Legume Generation supporting structure which includes general plant improvement strategies, data management, training, communication, governance, genotyping and phenotyping and last but not least, the overall project coordination and policy. These topics connect us with the other species-innovation communities within the project and give us platforms for trans-species legume topic exchange such as genome editing, ploidy, metabolic profiling, pod-shattering, flower-dehiscence, etc. We are intra-connected via the plant material and via the topics of common interest. We try to focus on specific germplasm to develop, which is not easy, because most of us have worked with different genetic resources so far. Hence, the way to combine these pools is to use the most advanced material from each partner as trait donor for the characters that have been described and elaborated so far. By crossing and introgression of traits and trait packages, we develop advanced breeding lines and link our partners´ activities.

Most partners have already established networks in research around lupins. To learn about the opportunities of our different networks and connect them as far as possible is the most important duty in forming the innovation community around lupins.

The research, pre-breeding and breeding activities are flanked by individual projects and activities beyond the Legume Generation project to increase the use of lupins and to follow new approaches like root-characters and root-microbiome. In this way, the LUPIC is

forming a platform where the work done for different investors is integrated and focused on impact.

Table 1. Members of the Lupin Innovation Community

First name	Second name	Role	Organisation
Fred	Eickmeyer	Private-sector plant breeder	ESKUSA
Irina	Schreiber	Private-sector plant breeder	ESKUSA
Ulrike	Lohwasser	Gene bank manager / Researcher	IPK
Thomas	Svoboda	Researcher	BOKU
Elizabeth	Ninou	Researcher	IHU
Donal	Murphy-Bokern	Policy specialist; Research director	DMB
Ivo	Rieu	Phenotyping; Researcher	RU
Eric	Visser	Researcher	RU
Helge	Flüß	Researcher	JKI
Amelie	Detterbeck	Private seed sector association	EURS
Lars-Gernot	Otto	Genotyping; Researcher	IPK
Jasmin	Karer	Communication and Network	DS
Catherine	Howarth	Researcher	ABER
Karolina	Susek	Researcher	IPG
Magdalena	Kroc	Researcher	IPG
Roberto	Papa	Researcher	UPM
Valerio	Di Vittori	Researcher	UPM
Juan Jose	Ferreira	Training; Researcher	SERIDA
Jose	De Vega	Data Management; Researcher	EI

We have detected gaps between breeding research and applied cultivar development. We can close these gaps by crossing and introgressing promising traits from the different research programs and bring the traits in line for the breeding process by pre-breeding. Here we have to build mutual trust, because we are all tightend in other obligations, cooperation-contracts and responsabilities for the plant material that we work on together with other partners in different constellations. To open these constellations to the common goal, ”cultivar development” needs continuous discussions, needs to convince partners about common goals and needs a certain amount of psychology to form a unit – the lupin IC - from different interests and approaches.

Table 2 lists our breeding and pre-breeding programmes and the partners, who are involved in the actual and planned crossing programme. We have one ongoing breeding programme in narrow leafed lupins and a recently established breeding programme in white lupins. Both are based on bitter types.

As soon as we have the first promising competitive variety candidates in the pipeline, we can activate our contacts to seed merchants and to food-processors to make use of our results (see the route to application).

Table 2. Lupin pre-breeding and breeding programmes within the lupin innovation community

Organisation	Prebreeding program	Breeding program	Species and traits
ESKUSA	Yes	Yes	**Narrow leafed lupin:** Grain yield, winter hardiness, herbicide resistance, protein content, alkaloids, diseases, alkaline soil tolerance
ESKUSA	Yes	Yes	**White lupin:** Grain yield, winter hardiness, anthracnose, alkaloids
UNIVPM	Yes	No	**White lupin:** Grain yield, alkaline soil tolerance, earliness, diseases
UNIVPM	Yes	No	**Andean lupin:** Grain yield, earliness, pod shattering, growth types, alkaloids
JKI	Yes	No	**Narrow leafed lupin:** Grain yield, growth types, anthracnose, seed shattering, protein content, alkaloids, mutant collections
JKI	Yes	No	**White lupin:** Grain yield, anthracnose
IPG	Yes	No	**White lupin:** Grain yield, seed size
IPG	Yes	No	**Andean lupin:** Grain yield, earliness
IPG	Yes	No	**Narrow leafed lupin:** Alkaloid biosynthesis and distribution

We have not yet started the discussion about intellectual property and benefit sharing within the lupin IC, however this will be an important topic for the next months in order to get a clear impression, what each partner expects from our cooperation and our common goal - the development of varieties. There are still some hesitations in exchange of plant material that we have to overcome.

Strategies for crop improvement

The lupin species have an extraordinary deep growing taproot, which helps them to grow on poor, sandy soils with limited water. Because of this feature, we believe that lupin species can play a major role in legume grain production as climate change progresses. But we have to prepare the species for the expected environmental conditions and we have to use and select them in a different way from the traditional breeding goals if we want to significantly improve grain yield. Without impressive grain yield increase there will be no further acceptance by the farmers and hence, no additional cropping area for lupins.

Turning big screws in lupin breeding

We have two big screws that we can turn to significantly increase grain yield and yield stability in the lupin crops:

1. Extending the growing season by turning a spring-sown summer-annual crop into a winter-annual crop. This leads to a strongly increased number of vegetation days as basis for improved resource capture. At the same time, the lupin can escape presummer drought. Pre-summer drought at spring sowing is the most severe limitation in yield stability and it is increasing with climate change progress.

2. Make use of the genetically broad genepool of bitter lupins, by i) introgression of traits from bitter accessions into sweet lupin varieties and preferably by ii) gene editing of

the alkaloid transport mechanism. We have the variation that we need in the genetic ressources to improve new cultivars. However short term thinking of return on invest keeps the applied breeding programmes from use of bitter types in the breeding nurseries.

The gene pools for the three cultivated **sweet** lupin species *L. angustifolius, L. albus* and *L. luteus* are very narrow. Serious breeding progress in terms of grain yield is no longer to be expected within these pools. On the other hand, a range of hitherto hardly used bitter forms in gene banks are available. In the 2015-2018 project funded by the German BLE (LupiZAV), we found that bitter genebank accessions of *L. angustifolius* from the Vavilov Institute contain a number of agronomically important traits that significantly can improve lupin varieties. From the INCREASE-project we have a further source of genetic resources in white lupin that we can smoothly introduce in our breeding activities.

The alkaloid-rich, bitter lupin varieties are not usable for the large animal feed market; however, their protein can be used technically in films and plastics (Luprotec) or as glue as well as in food technology (Luprome and Luprocess projects). The developments in these national projects are very promising and we want to extend their impact on international level.

To develop the above-mentioned agronomic characteristics for the feed market, these have to be introgressed by crossing into sweet lupins. Alternatively, genome editing could make the bitter gene pool of the lupin species directly available if the transport mechanism of the alkaloids from the leaf into the seed can be edited; i.e. development of a bitter lupin with sweet seeds. We work on both strategies. However, this alone does not make the narrow-leaved lupin any better and not more reliable in terms of grain yield. To exploit the grain yield potential, it is necessary to select further trait complexes with resource capture potential. We intend to select **winter-forms** of the lupin species. These could - sown in the fall - escape the pre-summer drought and use a longer vegetation period to build up yields. The trait complex 'winter hardiness' has then to be associated with late ripening, long, sturdy plants and firmness. Late ripening and long plants are, however, contrary to the previous pre-breeding and breeding objectives for lupins, which have been selected for 'short' and 'early maturity' for many decades. A new thinking about breeding goals is needed in this context.

Additionally, a safe herbicide strategy is urgently needed for conventional lupin cropping. We are searching for a non-gmo-herbicide resistance based on a mutation to cause resistance against sulfonylurea-herbicides. If we want to make the lupins independent from the soil type, we have to select for alkaline soil tolerance. We have single genotypes with this character, but we have to put a lot of effort in developing varieties with this character.

New cultivation methods and new breeding objectives should all be considered under the heading of "**resource capture**". This term includes photosynthesis days, stand space optimisation, root efficiency and, of course, climate resilience.
There is a lot of excellent basic research in lupins on specific traits and with state of the art molecular and analytical tools. However, there is a missing link between the basic research and applied cultivar development for release of varieties. We need to strengthen pre-breeding approaches (genetic analysis of observed characteristics; methods for reliable

trait identification; suitable quality analysis, etc.) as a connecting bridge and we need a courageous, bold breeding programme based on the available plant material including genetic resources. This requires an (international) division of labour and close cooperation between breeders and scientists in the pre-competitive area even between breeding companies. The cooperation should be based on the individual legume species, as is already being pursued in the case of the current Legume Generation project . The impetus in this project comes from the applied breeding, which in turn takes the necessary breeding objectives from the conditions of agricultural practice. The agricultural expectations on lupin varieties are competitive and enough income of legume cropping in comparison to cereals and other crops. ESKUSA has set itself the goal to develop varieties of narrow-leaved lupin with 4 t/ha reliable grain yield and 40 % protein content (our "40/40" approach).

Financing the Lupin Innovation Community

At the moment, the activities of our LUPIC-group are dependent on public funds. Most of our individual partners have permanent positions in their organisations and institutes, however, in some organisations there is only a small and/or fixed budget for lupin activities. ESKUSA as a private company has only a very limited income of royalties from the sales of its variety ´ESKUBLUE´. ESKUSA finances its lupin breeding programmes actually from public funded research projects plus income from rubber dandelion and arnica production. We aim at two to three public funded lupin projects in parallel to cover our most important lupin development activities. For example, a three-year national funded project LupiRhiz about root morphology, root exudates, soil microbiome etc. will start in spring 2025. Our national research projects in Germany start with the prefix Lup—or Lupi- to have a recognition value.

Our goal is to become independent from public funds. This can only be reached if we earn sufficient royalties for marketed lupin varieties or we manage to get financial engagement of seed merchants or lupin processors in our LUPIC activities. ESKUSA will get first income from seed merchant engagement starting in 2025 for some forage legumes (vetches and fodder pea). A small start, but a start.

In rubber dandelion ESKUSA pays the former project partners in the meantime up to 100.000 € per year for their analytic-services and we are in the process to do the same for arnica – a medicinal plant.

The food- and feed-processing industry and seed merchants as well as plant breeders should serve more as financial sources for research activities in plant breeding research. However, without successful varieties we will never reach this point. Therefore, we have to work on successful varieties.

The plan for boosting breeding

White lupin

The plan to boost white lupin is illustrated in Figure 3.

In white lupin, we start with genebank accessions that come mainly from the INCREASE project. IPG and UNIVPM use several descriptors which characterise and structure these accessions on phenotypic and genomic level. Single seed descent lines are already developed. For Legume Generation, this material has been multiplied. We will evaluate this material for the most important traits: seed yield, anthracnose resistance/tolerance and alkaloid level in field and laboratory tests, together with some bitter accessions from the Vavilov Institute in St. Petersburg that have been multiplied by ESKUSA. ESKUSA as a private breeding company started a new breeding programme with white lupin in the preparation of the Legume Generation project. The goals that we want to reach within the project are improvement in the above-mentioned traits to reach competitiveness with already registered varieties. In our first field trials, we have identified a few promising grain yield accessions. These accessions will be the basis for incorporation of further traits like anthracnose tolerance, low alkaloid content and seed size. We will do first crosses with this material in 2025, and we will cross with sweet cultivars. This programme is quite young; we are still in the process to establish variation instead of strong selection of lines. We plan to repeat yield trials at three locations (JKI, IPG, ESKUSA) with spring sowing in 2025.

Andean lupin

The plan to boost Andean lupin is illustrated in Figure 4.

Here we also start with genebank accessions since there are no European cultivars existing. Beyond genetic resources from genebanks there are South American landraces available. Since several accessions have a very long development time, our priority is to find material that can be cultivated for grain yield in specific regions and can be multiplied in Europe. In 2024, this material was multiplied in the greenhouse. We will start with field evaluation of a selected set of accessions as soon as there are enough seeds for field trials available. We have to identify suitable regions for cultivation and learn which agronomical characters are needed there. Another approach is winter survival of Andean lupin. This feature could help seed multiplication. This programme has not yet reached the pre-breeding level. Everything is depending on the possibilities to multiply and produce seeds.

Narrow-leafed lupin

The plan to boost narrow-leafed lupin is illustrated in Figure 5.

In this species, we use bitter genebank accessions to have a large variation and to follow a trait-based breeding scheme. We already found several important agronomic traits in these bitter accessions that we want to introgress into sweet lupin varieties as well as to pyramid genes in a long-term approach. From this material, several lines have been selected for about seven years. Being useful as trait donor, parts of this material have reached good levels of grain yield and protein content to be used for applications in food-

and technical-protein-processing. One variety for green manure has already been registered from this material. We want to improve sweet varieties with characters from bitter forms e.g., calcareous soil tolerance (test was established in 2023), high protein content and plenty pod formation by introgression-breeding. First crosses have been done and in 2025 we expect to have the first segregating F2-populations at JKI for genetic analyses and inheritance studies of several traits. Several lines have been multiplied and have been tested in multilocus field-testing in 2024. They will be retested in 2025.

We have two partners (ABER in Wales and IHU in Greece) who perform field trials with different focal points on diseases and on drought and soil quality. We have two partners (IPK in Germany and SRU in Netherlands), who will do tests under controlled conditions for heat- and drought-stress tolerance. We have one partner (BOKU in Austria) who will search for resistances/tolerances against soil borne fungal diseases. We have three partners (IPG in Poland, UNIVPM in Italy and JKI in Germany) who work with multidisciplinary approaches in lupin species including phenotyping, genotyping, molecular markers, quality analytics, different tests and field trials. Finally, we have one private breeding company (ESKUSA in Germany) with greenhouse and field-testing capacities that follows a short term, mid-term and long-term strategy in cultivar development of lupin species.

The LUPIC-partners have complementary expertise. However, they focus on different research topics and work with different species. A key for the success of the LUPIC will be cooperation over different species. We need to develop a trans-species point of view in our activities to join our forces, grow together and to solve problems in common.

To be an attractive cropping option for farmers, lupins need a very big progress in grain yield and yield stability in future varieties. This requires consideration of how lupin can be developed to better capture resources providing the foundation of increased yield. First steps have been done and we will follow our concepts within the frame of Legume Generation. We think that we have a good basis. Beyond this we expect a long-lasting partnership to be able to really improve future lupin varieties.

The route to application

Each private breeding programme must respond to market needs as expressed by farmers' choices. In LUPIC, we derived our most important breeding goals from farmers' needs and transfer these needs into a cultivar-development-oriented pre-breeding and breeding programme.

There are three ways to exploit improved lupins. The "traditional" or common way is via variety registration and national-/EU-listing for potentially 'big' cultivars followed by distribution to farmers via established seed merchant companies and distribution systems. The second way is contract production of exclusive 'varieties' in a closed loop with bilateral contracts as an alternative for 'small' varieties with special properties. The third way is contract breeding of exclusive plant cultivars for a seed merchant company. In this case, the breeder acts as a service-provider and is paid for the know-how and the breeding activities provided. All three ways are open and are followed by ESKUSA.

Official variety registration and national-/EU-listing

For ESKUSA, seed multipliers/merchants such as DSV, Feldsaaten Freudenberger and others provide the route to market, including through holding field demonstrations etc. As soon as promising germplasm for variety registration and official listing is ready, these companies will be asked to demonstrate market coming varieties. Relationships to these companies are established and active. For example, ESKUSA's narrow leafed lupin variety ´ESKUBLUE´ is produced and marketed by Feldsaaten Freudenberger. Via the project partner Euroseeds further seed multipliers and merchants can be reached for example to address certain European regions.

Contract closed loop production of exclusive varieties

Another active contact is Lupino AG, a company that is already processing food-protein from ESKUSA´s bitter narrow leafed lupin material with a unique membrane-filtration-technique. Lupino AG will triple its production capacities starting with the year 2025 to about >300 tonnes of food-grade protein. This amount is not enough to justify a variety registration. Therefore, contract production of bitter narrow leafed lupins in a closed loop will be carried out without variety registration for this purpose. High protein lines have been selected and have been started to be multiplied in a common project (Luprome).

Contract breeding as a service

ESKUSA has first breeding-service-provider-agreements for other legume species (forage and catch-crops) with the seed merchant Feldsaaten Freudenberger. In this case, the breeding material belongs to the customer and ESKUSA acts as a service provider in breeding.

To summarise, direct ways to bring the lupin material, that we will develop in Legume Generation, to the consumer already exist. Apart from this, ESKUSA wants to stress that further breeding company partners are highly welcome to join our innovation community; there is a lot of work to do and to share in order to develop the lupins to their deserved position legume production.

Sites and field experiments

Figure 1. Map of trial locations and main focus activities in lupins

In our group, we have four locations at which we are able to carry out plot field trials for grain yield in the frame of the project. That is JKI, IPG, UNIVPM and ESKUSA. In the sowing year 2024 – due to limited amounts of seeds - we were only able to sow row or double row trials at these locations and get first impressions on grain yield.

In Wales (Aber) and Greece (IHU) we have limited (time and space) testing capacities to complement our grain yield trials with observations regarding fungal diseases and drought and heat stress. Yield doesn´t play the primary role at these locations.

The testing facilities at SRU, IPK and BOKU focus on specific traits. At BOKU, soil-borne-fungal disease resistance tests are in development, which gave first results on the differences in *Fusarium oxysporum* behaviour of narrow leafed lupin accessions. Sclerotinia results will follow. IPK carried out a first drought tolerance test in greenhouse pots for white and narrow leafed lupins. The results from IPK will be the basis for the material selection for a heat tolerance test at SRU to be carried out in 2025.

An overview about the geographic distribution of our partners is given in Figure 1.

We hope to be able to find further testing locations in the southwest and in the Scandinavian area of Europe. A first request for cooperation to the company CERIENCE in France (partner of the BELIS-project) has been sent out.

Innovation networking

Dissemination

We plan to invite further stakeholders like food-processors, feed-processors, breeding tool developers (gene-editing, NMR-metabolom-profiling; double haploids) to present state of the art developments for new input in our lupin IC. For announcing these stakeholders, we can use the Legume Generation newsletter as well as for presentation of activities within our group. For short term communication, we can use the email-distributors list of Legume Generation.

We have an exchange of plant material that keeps us connected.

To disseminate results to the outside, we can use breeders or seed congresses, national or international legume or lupin congresses. Another way is to use the regular contacts with seed merchants to make aware of our activities and outcomes in a very concrete and direct way.

Exploitation

We are in close business contacts with seed merchants and seed multiplication companies that are able to bring the developed cultivars to the farmers. These companies carry out regular demonstration trials of new coming cultivars for farmers. When lupins are marketed on a free market, we need to have Plant Breeder´s Rights (PBR) before the start of selling seeds. These PBR are normally applied by the breeder or by a seed merchant. Some public institutes also apply for PBR. That means we have to negotiate within our IC, who will apply for PBR as soon as there are variety candidates in the pipeline.

On the other hand, we have a close contact to a food-processing company for lupin protein – the Lupino AG. Lupino AG has developed a unique process to generate food-grade protein from bitter lupins. We are working together in projects and are in continuous contact about processing bitter lupins in the food industry. Here, we think about bilateral contracts and keeping the IP in a closed loop.

Our research partners are free to use their research results or their tools to publish and develop their international reputation. Furthermore, we hope that some tools from public institutes can be offered as a service for breeders. Many universities have a commercialisation department for those purposes.

Communication

For internal communication, we have established monthly online meetings to keep us mutually informed about the work-progress and to exchange news and ideas within our

group. Beyond that we have bilateral or multilateral exchanges of emails with information about our activities and about the state of the plant material.

External communication

Below we present some examples of the external communication and dissemination about our activities within the project and about our lupin activities in general:

18.01.23	German society for lupin (LeguNet) - talk about lupin breeding
30.03.23	Meeting at BayWa, Munich with people from "New Protein Solutions" group
03.07.24	Annual lecture at University of Applied Sciences Erfurt about lupin breeding
02.10.24	Visit of seed merchant Freudenberger at ESKUSA – contract breeding of peas and vetches agreed; discussion about green manure lupins
08.10.24	2. Leguminosenkongress (DAFA-BLE national legume conference) in Leipzig - talk and poster about Legume Generation and breeding in ESKUSA: https://www.legumehub.eu/news/national-legumes-congress-leipzig-2024/
05.10.24	BLE Innovation Days – Talk about Luprocess-project (food grade protein concentrate from bitter lupins)
14.11.24	Online meeting with paper industry about project Luprotec (films and coatings from lupin protein)
22.11.24	Bavarian Economy – Talk about Bioeconomy – with example lupins

Legume Hub

We will use the Legume Hub and the project website for international dissemination of our structure, our results and of our goal. The Legume Hub is Europe's open-access knowledge platform on legumes that guarantees a permanent availability of the project outputs. Furthermore, we will use national channels for dissemination like associations and societies such as GFPi, BDP, DAFA, as german examples. We are members of already existing network structures that can disseminate our project results like the lupin society or the german LeguNet.

Outreach ambassador

We have not appointed an outreach ambassador for the LUPIC group. However, we have monthly online meetings to exchange our ideas, information, upcoming events and plans for activities. We use this platform and appoint in a case-by-case mode a certain person from our group to distribute information for example to the Legume Hub or to the communication channels within the project.

Finance and business models - markets

In the OECD-list of lupin varieties eligible for seed certification we found that there are just a few original breeding programmes in Europe that regularly produce new varieties. However, there are a lot of seed distributers in Europe that multiply and sell varieties. Varieties from Chile or Australia are of low relevance in Europe. They seem to be not adapted enough to be grown here on a large scale. This situation offers opportunities to successful European breeders to negotiate with the seed merchants and seed multipliers about access to new varieties, for example on the traditional royalty basis.

Beyond this, new business models such as contract breeding or contract seed production could be discussed with interested seed merchants, seed multipliers or with feed- and food-processors. Governance support on these topics from our project partners, especially with the customer-group of feed- and food-processors, is highly welcome. Until now, this customer-group is outside the business of breeders or seed producers. Single companies like the Brotbüro in Hamburg start to do contract seed production with farmers for food applications directly. The feed industry has only limited connections with lupin breeders or multipliers, because most of the produced lupins are not on the free market, but stay on the farms for direct feeding of animals. Unfortunately, the company ProLupin® as the biggest food processor for lupins went insolvent and was sold recently to an Australian protein production company. Our own food-processing partner Lupino AG is still very small. Several SME start-up food companies only need a few tonnes of lupin grains and many of these start-ups vanish from the scene within short time. A feed- as well as a food-processing industry is missing that waits for lupins. Press-cakes from oil crops or by-products from starch extraction of peas or potatoes offer low prices for protein.

The Lupin Innovation Community can only be maintained by income from successful varieties and by sharing an adequate future income for partners, depending on the contribution of the development of a given variety or even a given breeding programme. We have to develop awareness of such thinking.

Training

We already use proposed webinars to get a better understanding on certain topics like IP, variety registration, standard material transfer agreements etc. We are grateful for support on data-collection, -structuration, -processing and data management from the colleagues within the Legume Generation project. Common structures are urgently necessary to connect different research and breeding units. We also expect impact from new kinds of phenotyping-, screening- and testing-tools from our project partners. From the Lupin IC, we also want to propose topics that are relevant for trans species approaches like pod shattering, flower dehiscence, genome editing, metabolomic profiling, double haploids, polyploids, interspecific hybridisation etc.

We have started a discussion about topics such as species improvement with our partners from data management, but we need also support from our partners that work 'Governance, finance, and business development ' and 'Communication, dissemination and exploitation'.

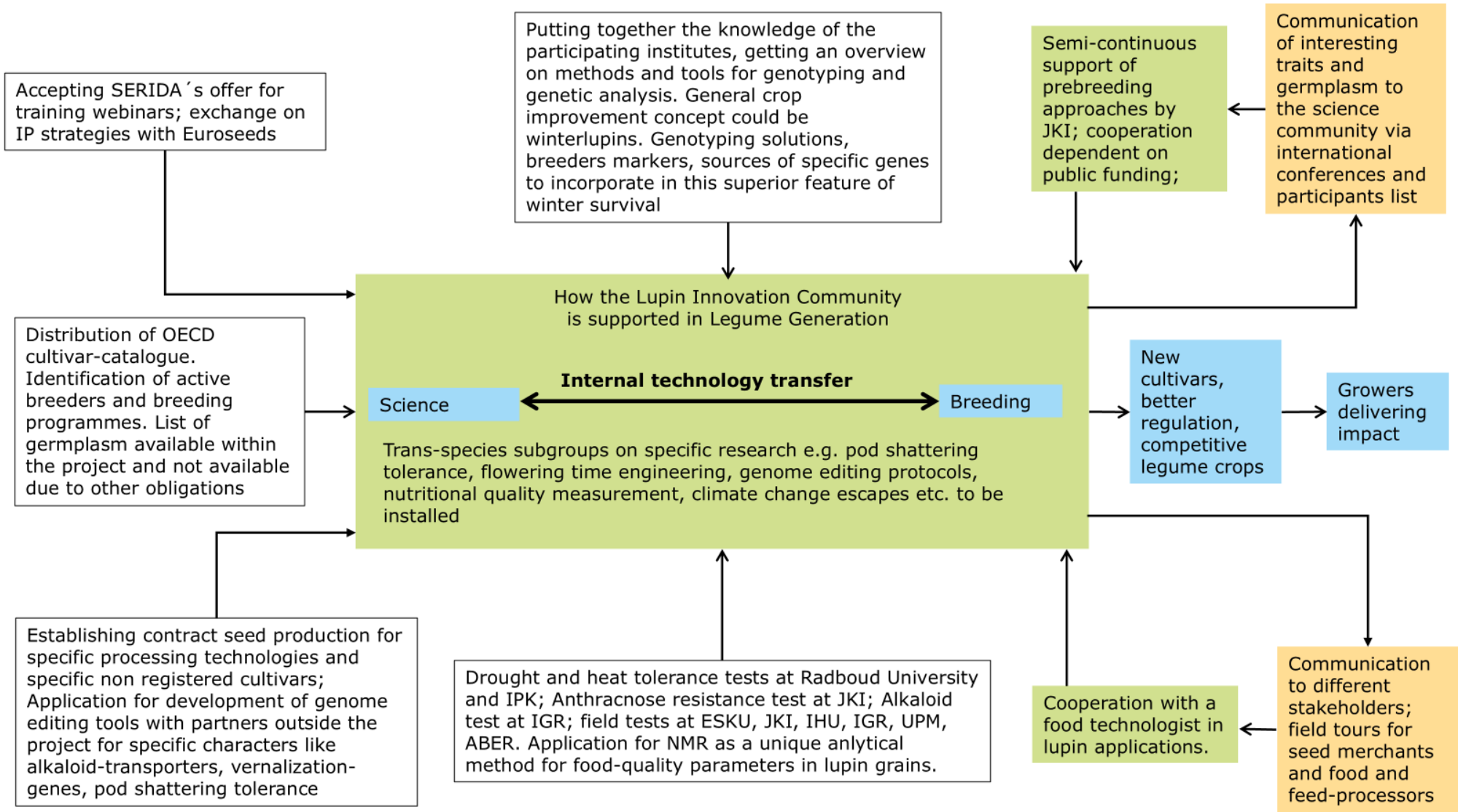

Figure 2. How the Lupin Innovation Community is supported in Legume Generation

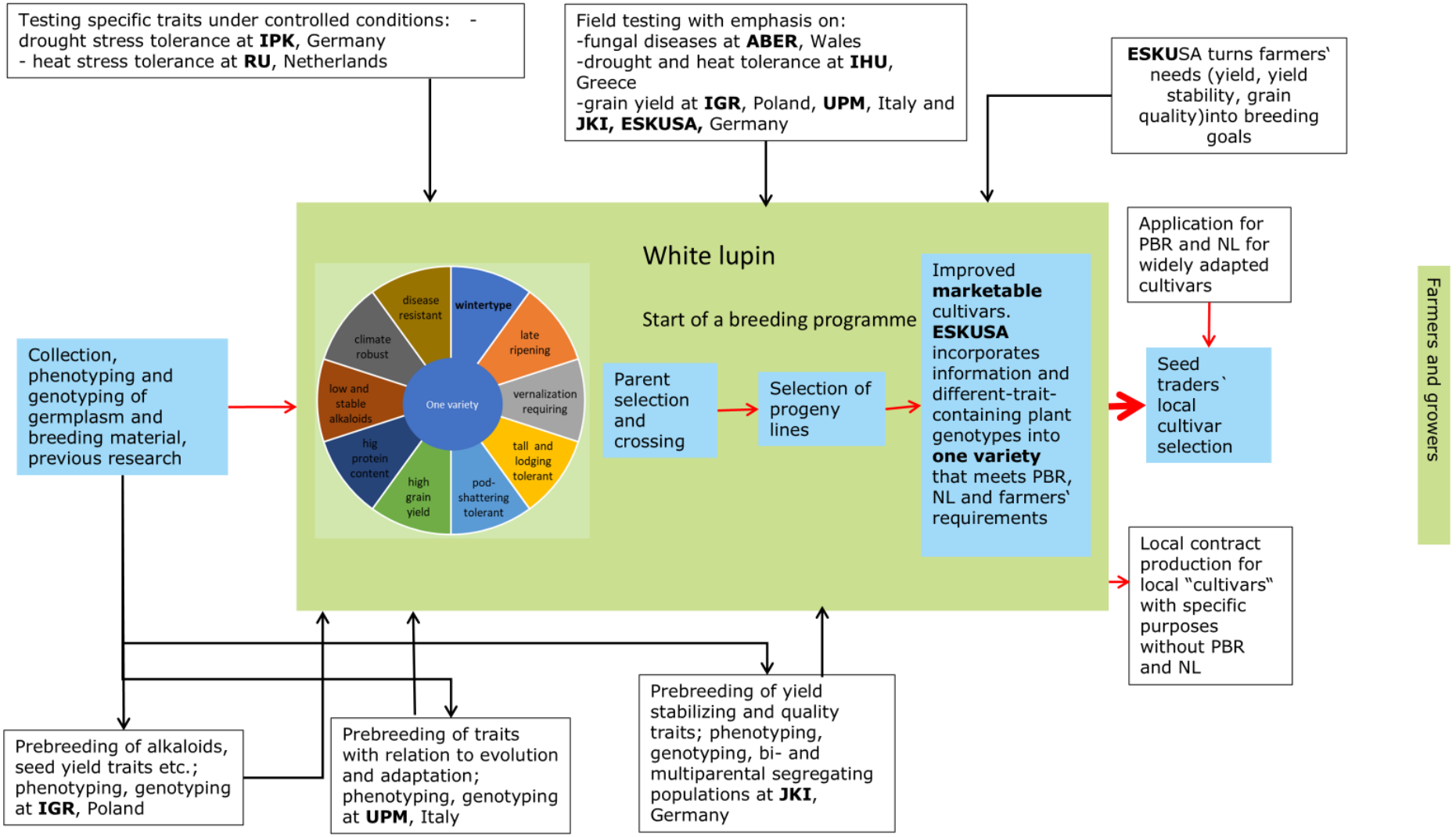

Figure 3. Innovation pathways for white lupin

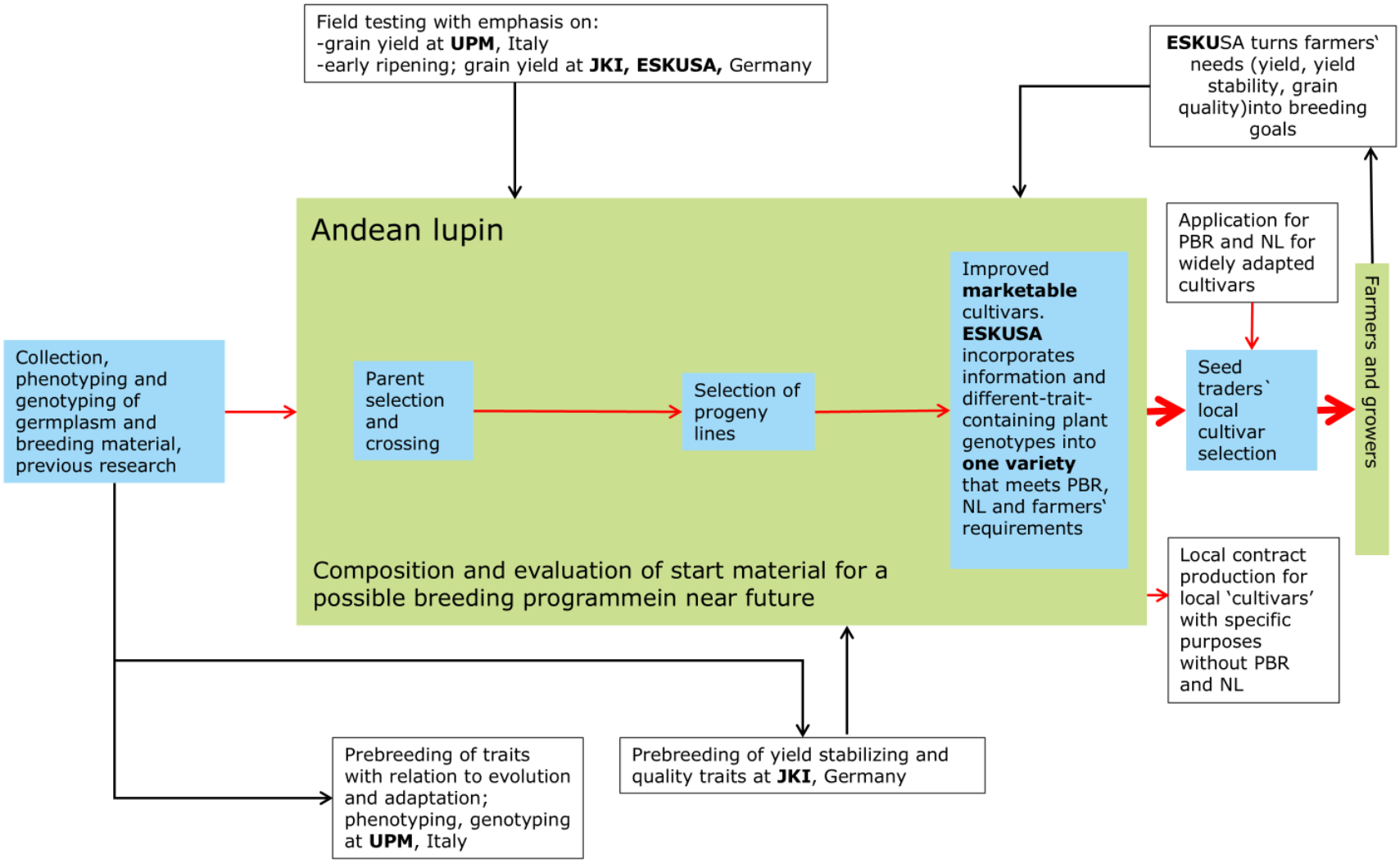

Figure 4. Innovation pathway for Andean lupin

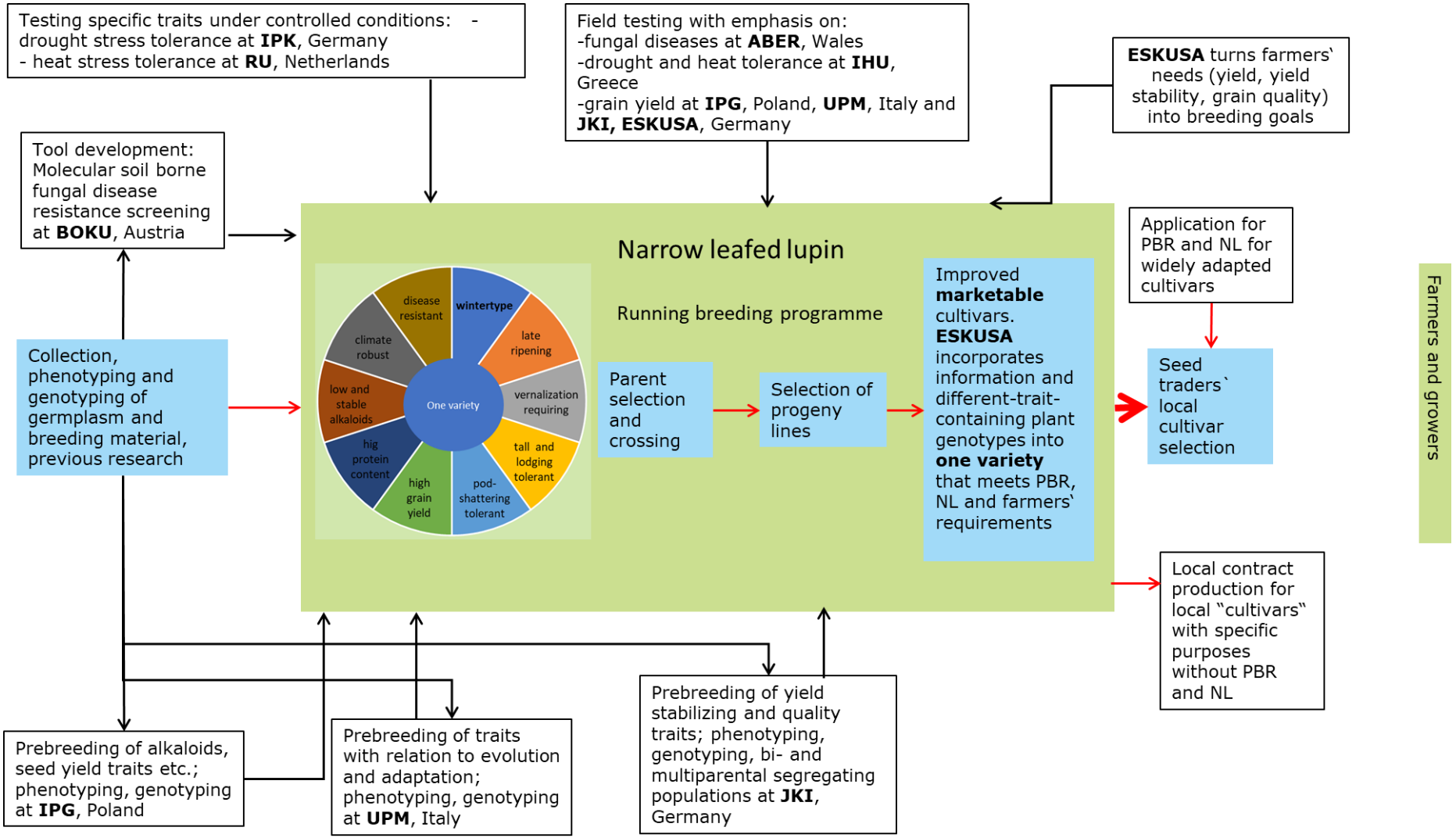

Figure 5. Narrow-leafed lupin