PULSES FOR THE MEDITERRANEANS: CONTRIBUTION OF A SIMPLE CROP MODEL TO PULSE-BASED CROPPING SYSTEM DESIGN UNDER LOW WATER RESOURCE AVAILABILITY

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Introduction

In the Mediterranean drylands, erratic and deficient rainfall as well as limited access to fertilizers are primary constraints to crop production. Inclusion of pulses in crop sequences can alleviate the demand for N fertilizer, provided that N fixation is supported by adequate water management. Solutions to improve water use efficiency can be sought at different scales: either at the field scale, by optimizing irrigation amount, timing and frequencies, or at the farm scale, by sharing irrigation water adequately amongst the crops grown simultaneously on the farm. Inducing deep changes in crop management and farm structure can be costly and highly risky in areas where subsistence agriculture prevails and should be supported by ex-ante analyses. We show here how a simple mechanistic crop model can be helpful for ex-ante assessment of agricultural innovation at field and farm scale and contribute to designing more water use efficient pulse-based system for the Mediterranean region through two examples.

Materials and Methods

A Simple Simulation Model (SSM) has been developed by Soltani & Sinclair (2012) and shown to be robust in simulating various legume species (Vadez et al., 2013; Marrou et al., 2014; Ghanem et al., 2015). In a first study, SSM was used to simulate a common bean field in the area of Castelnaudary in the South of France. Four irrigation scenarios were compared: (1) current farmer’s irrigation schedule, and (2,3,4) model triggered irrigations (30 mm irrigation applied whenever the fraction of soil transpirable water (FTSW) fell below 0.5, 0.35, and 0.2, respectively. In a second study, we encapsulated the SSM model into a summary farm model in order to simulate different strategies for sharing irrigation water on a 5 ha farm growing durum wheat and chickpea with limited total water resource (2500 m³ per year). Two modalities of irrigation (Lrf: all water allocated to wheat; Lw: 50 mm applied to chickpea and the rest to wheat) were crossed with 5 different crop rotations. Productivity, water use and water use efficiency per crop or rotation were compared between scenarios in both studies.

Results and Discussion

At Field Scale

A threshold of 0.35 or 0.5 allowed achieving the same yields as farmer’s practices, but cumulated irrigation was reduced by 30% with the 0.35 threshold (Fig. 1), resulting in greatly improved irrigation water efficiency. Analysis of soil water dynamics showed a mismatch between crop requirement and water supply by farmers. (Fig. 2).

Figure 1. Simulated cumulated irrigation (model triggered and farmer’s irrigations)

Figure 2. Irrigation frequency dynamics vs. days after sowing (DAP) with farmers’ and model triggered irrigations
At The Farm Scale
Food production and irrigation water efficiency were hardly affected by irrigation strategy, but N fertilizer requirements were drastically reduced when irrigating legumes (Lw). In addition, the Lw strategy resulted in improved irrigation water efficiency on the wheat cycle: saving all the water for wheat (Lrf) may allow greater water-limited potential yield for wheat (Figure 3; A), but the low amount of organic N recovered from rainfed legume residues may not allow the water-limited yield to be achieved (B) and result in lower irrigation water use than the Lw strategy (C).

![Figure 3](image)

Figure 3. Relation between irrigation applied on wheat and water limited wheat yield - $Y_w$ (closed symbols) or water and N limited $Y_{N,w}$ (open symbols).

Conclusions
Room for manoeuvre to design water efficient systems have been shown. The farm-scale study highlights the importance of considering N and water simultaneously.

References
LEGUMES IMPROVED DRYLAND GRAZING SYSTEMS IN NEW ZEALAND

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Introduction

In this paper we summarize the use of lucerne (Medicago sativa L.) and subterranean clover (Trifolium subterraneum L.) in dryland grazing systems in New Zealand over two decades. These systems are located in the rain shadow of the Southern Alps. Low annual rainfall (350–800 mm) and high potential evapotranspiration (1400–1600 mm) are coupled with strong Northwest winds that produce daily evapotranspiration rates up to 8 mm. Together the climate and high soil variability (60–300 mm of water holding capacity) leave a 3–4 month window of reliable pasture growth. Each year the spring-born lambs are sold for export or finishing by specialist producers to enable the farm to destock and avoid the dry summer period. We aimed to develop sustainable grazing systems in this environment. This required plants to maximize spring water use efficiency, and provide a bulk of nutritious animal feed for grazing in situ during and shortly after lactation. This paper summarizes 15 years of on-station research and on-farm demonstration that has transformed some of these dryland farms. The research was based on first principles associated with the need to convert limited water to high quality feed to meet animal demand.

Materials and Methods

A series of field experiments at Lincoln University assessed the relative merits of a number of plant species to fit into dryland farm systems. The first compared chicory (Cichorium intybus), red clover (T. pratense) and lucerne grown under irrigated (Brown et al., 2005) and dryland (Brown et al., 2003) conditions. The second assessed pasture production from cocksfoot (Dactylis glomerata) grown with or without nitrogen and irrigation (Mills et al., 2006). In the third, the above and below ground response of an irrigated lucerne monoculture to short (every 28 days) or long (every 42 days) grazing durations separated partitioning responses from moisture (Teixeira et al., 2007). A comparison of dry matter production, spring water use efficiency, pasture persistence, and animal performance was then made in a dryland grazed experiment of six pasture combinations in six replicates over nine years (Moot et al., 2008; Mills et al., 2015). These results informed farmers of appropriate pasture options and led to increased demand for technology transfer (Moot, 2014).

Results and Discussion

Of the three deep-rooted forages tested, lucerne was the most productive and persistent (Brown et al., 2003). A strong seasonal response of nitrogen and carbon remobilization from lucerne storage organs to shoots was shown in spring (Teixiera et al., 2007). In contrast, there was a consistent switch to recharge these storage organs in autumn to return the reserves to about 4 t DM ha⁻¹. This seasonality of a fall dormancy 5 cultivar was then matched to grazing systems to provide a bulk of feed supply during the period of highest animal demand. Farmers took this information and were assisted to implement lucerne grazing strategies to maximize animal production and minimize the risk of animal health issues (e.g. Avery et al., 2010).

Cocksfoot data showed that nitrogen was actually limiting production more than water in these dryland systems. The use of legumes to provide the nitrogen supply was then explored in a pasture species trial. This confirmed higher animal and pasture production from legume-dominant pastures which resulted from greater spring water use efficiency (Moot et al., 2008). Lucerne was shown to be the most productive species but subterranean clover-based pastures provided earlier spring growth and are now also being utilized for early spring lamb production (Brown et al., 2006).

Conclusions

Dryland pastures are always nitrogen deficient so they are inefficient users of soil water unless they are legume-dominant.

Acknowledgements

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References


NOVEL APPROACHES TO OPTIMIZE GRAIN LEGUME CROPPING SYSTEMS

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Introduction
The specialization of current farming practices in Europe led to a reduction of diversified farming systems that included grain legumes and an increase in negative environmental impacts. Although grain legumes have the potential to reduce negative environmental impacts such as greenhouse gases and provide positive rotational effects when integrated into agronomically sound cropping systems (Reckling et al., 2016) farmers tend not to grow them. Novel approaches to optimize grain legume production systems are needed in order to increase their attractiveness. The objective of this paper is to explore and evaluate optimized cropping strategies in a participatory approach with farmers and agronomists that (i) farmers are interested in implementing, (ii) are relevant, and (iii) are novel either to individual farmers or to most farmers in the region.

Materials and Methods
In the case study region of Brandenburg (Germany), a participatory approach is implemented with farmers and agronomists. The farmers are part of two large demonstration networks with 71 farms across Germany. Optimization strategies for soybean and narrow-leafed lupin are tested in on-farm and on-station experiments that are designed in an iterative process. For the on-farm testing, agronomists and farmers decide together on the experimental design, monitor the performance and evaluate the outcome before re-designing the experiments for the next year. This documented learning cycle continues from 2014 to 2017 and includes various treatments. Results provide input for the design of on-station experiments and vice versa.

On-station experiments are designed by agronomists after consultation with farmers. They provide ideas on treatments that cannot easily be tested in on-farm experiments, require detailed measurements and replications, and a repetition over several years under similar conditions. Results are of scientific relevance and serve as a platform for discussions during field days and stakeholder workshops.

For designing optimization strategies of cropping systems with lupin, farmers provide information on their current rotations and management practices, and ideas on potential changes that could improve the overall cropping system. The crop rotation planning tool ROTO 4.3 is used to explore the effect of different alternatives on the agronomic performance of cropping systems including yield, nitrogen and carbon balance, nitrogen leaching and different weed infestation risks. There is a feedback loop of the results from the cropping system design and the experimental testing (Figure 1, A).

Results and Discussion
The iterative process with farmers and agronomists led to the design, implementation and evaluation of several on-farm experiments with diverse treatments. Wider spacing of lupin was one novel strategy to control weeds. Inoculation of lupin has so far shown no effect in the experiments. In soybean, reduced tillage achieved similar yields compared to ploughing with less energy input. Farmers already adopted new strategies after the on-farm testing on their fields including diversifying their soybean cultivars to reduce agronomic risks and provide options for both food and feed markets.

The comparison of soybean cultivars with narrow-leafed lupin in on-station experiments showed greater yields of two soybean cultivars in 2015 under irrigation and equal yields under rainfed conditions (Figure 1, B). In 2014, lupin and one soybean cultivar failed due to diseases. Yields of soybean and lupin were increased significantly by irrigation in 2015 which was a particular dry year but not in 2014. Irrigation is a strategy that needs to be further tested. The participatory process with farmers supports the collective learning, leads to changes in attitudes towards grain legume cropping systems, and affects the willingness to experiment with new cropping strategies (Bloch et al. 2015).

The evaluation with ROTO showed positive pre-crop effects of lupin on yields of subsequent crops and risks of nitrate leaching that could be reduced with cover crops.
Conclusions
The participatory approach with farmers and agronomists provides several novel strategies including (i) soybean cultivation, (ii) wider spacing to allow mechanical weed control in lupin, (iii) reduced tillage and the cultivation of a range of soybean cultivars. The integration of the different methods supports an actor-oriented research process.

Acknowledgements
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References
ONE FIELD – TWO CROPS: INCREASING PROTEIN YIELD AND NITROGEN FIXATION WITH WHEAT-PEA INTERCROPS

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Introduction

Intercrops are mainly grown in traditional agricultural systems, but there is an increasing interest especially in cereal–legume intercrops in arable farming systems in temperate regions for increasing productivity and sustainability (Neugschwandtner & Kaul, 2014, 2015).

Materials and Methods

A field experiment was conducted in 2010/2011 and in 2012/13 at the Experimental Farm of BOKU University in Raasdorf which is located to the east of Vienna (Austria). The soil is a silty loam classified as Chernozem. Average long-term precipitation and temperature are 538 mm and 10.6°C. Pure stands of wheat (Triticum aestivum L. cv. ‘Xenos’) and pea (Pisum sativum L. cv. ‘Creeke’) were established with 300 (wheat) and 80 (pea) viable seeds m-2. Both are facultative winter/spring cultivars. Four intercropping mixtures were sown in replacement series consisting of following wheat:pea ratios (%): 75:25, 50:50, 25:75 and 12.5:87.5. Sowing was performed in autumn and in spring. Harvest was in July. Results are summarized for both sowing dates and both years. The land equivalent ratio (LER) which indicates a yield advantage or disadvantage of intercrops compared to corresponding pure stands was calculated according to Mead & Wiley (1980).

Results and Discussion

Wheat was the dominant partner in the intercrops. With decreasing share in the intercrops, the wheat yield decreased slightly whereas the pea grain yield decreased rapidly (Fig. 1a). All intercrops had a grain yield advantage over corresponding pure stands ranging from 12–20%. The highest grain yield increase was found in the 12.5% wheat and 87.5% pea intercrop (Table 1). The protein content of both species increased as its share decreased in the intercrops. For wheat it increased from 10.0% (pure stands) to 12.7% (12.5% wheat in the mixture) (Fig. 1b). With a lower share on the intercrops, the protein yields of wheat decreased just slightly but those of pea decreased faster (Fig. 1c). The LER for protein yields showed that intercrops were by 16–32% more productive than pure stands, with the mixture of 12.5% wheat and 87.5% pea showing the highest value (Table 1). The soil mineral nitrogen after harvest was higher in intercrops than in wheat pure stands, showing that intercrops might be a better pre-crop (taking also into account the N-rich legume residues) (Fig. 1d).

Figure 1. Grain yields (t ha⁻¹), (b) Protein contents (%), (c) Protein yields (kg/ha) and (d) Soil mineral nitrogen (kg NO₃⁻N ha⁻¹) after harvest in a soil depth of 0–90 cm in the pure stands in intercrops of wheat and pea.
Table 1. Land equivalent ratio (LER) of intercrops for grain and protein yield and yield

<table>
<thead>
<tr>
<th>Wheat:Pea (%)</th>
<th>Land Equivalent Ratio</th>
<th>Grain Yield</th>
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<tr>
<td>75:25</td>
<td>+18%</td>
<td>+26%</td>
<td></td>
</tr>
<tr>
<td>50:50</td>
<td>+12%</td>
<td>+18%</td>
<td></td>
</tr>
<tr>
<td>25:75</td>
<td>+18%</td>
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<td>12.5:87.5</td>
<td>+20%</td>
<td>+32%</td>
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</table>

Conclusions
Intercrops of wheat and pea resulted in higher yields than the pure stands of these crops. Grain yields were up to 20% and protein yields up to 32% higher. Additionally, intercrops leave more mineral nitrogen in the soil after harvest, thus, they might be better pre-crops.

References
TO PEA OR NOT TO PEA? COMPARATIVE INSIGHTS ON LEGUME GRAIN AND GRAIN PROTEIN YIELDS FROM EUROPE, NORTH AMERICA AND OCEANIA

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Introduction
Growing more grain legumes in Europe is currently suggested for the European Union to increase its domestic production of protein crops, and to decrease its dependency on soybean imports. Although several grain legumes may be candidate protein crops, pea (Pisum sativum)—and more recently, soybean (Glycine max)—were the most grown legume species in Europe over the 50 last years. This preferential allocation might have shifted other legume species to minor cropping areas. Comparing legume grain and grain protein yields for a broad range of species may help agronomists and decision-makers target potential protein crops for European agriculture. Here, we compare the legume grain and grain protein yields of 22 species with pea using a meta-analysis based on field experimental data. Comparative insights are provided not only from Europe but also from North America and Oceania—two regions growing more grain legumes than Europe.

Materials and Methods
We selected 61 peer-reviewed articles comparing the yields of grain legumes grown as pure crops in Europe, North America and Oceania. We collected agronomic experiments comparing directly one or more legume species with pea, used as reference crop. Each agronomic comparison was systematically carried out at the same field sites during the same growing seasons under the same crop management techniques. In total, we extracted grain yields from 2,196 unique species×field site×growing season×crop management technique combinations. Grain protein yields were determined by multiplying grain yields by the percentage of crude protein in grains, reported individually for each species into the Feedipedia database. Legume species were compared with pea by calculating grain yield ratios and grain protein yield ratios across all agronomic experiments. Mean ratios were estimated using mixed-effect models. Uncertainty in mean ratio estimates was analysed by computing 95% confidence intervals. For each region, legume species were ranked separately according to both estimated grain yield and grain protein yield ratios. Finally, we identified species displaying lower, similar or higher performances than pea.
Results and Discussion

Table 1. Grain yield ratio and grain protein yield ratio of 22 legume species compared with pea (*Pisum sativum*) in Europe, North America and Oceania. The symbols ‘−’, ‘0’ or ‘+’ correspond to species displaying lower, similar or higher performances than pea (*P*<0.05), respectively. The symbols in brackets correspond to mean ratios estimated using field experimental data from only one or two articles.

Species are listed alphabetically

<table>
<thead>
<tr>
<th>Species</th>
<th>Europe Grain Yield Ratio</th>
<th>Europe Grain Protein Yield Ratio</th>
<th>North America Grain Yield Ratio</th>
<th>North America Grain Protein Yield Ratio</th>
<th>Oceania Grain Yield Ratio</th>
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<tr>
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<td>−</td>
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<tr>
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</table>

More species were compared in Oceania than in Europe and North America. Faba bean (*Vicia faba*) show lower performances than pea (*Pisum sativum*) in North America, displays similar performances than pea in Europe, and outyields pea in Oceania. Soybean has productivity levels similar than pea in Europe, but a small number of soybean data is available in this region. In all regions, chickpea (*Cicer arietinum*), lentil (*Lens culinaris*) and common bean (*Phaseolus vulgaris*) give lower grains yields and grain protein yields than pea. Grass pea (*Lathyrus sativus*) in North America and Oceania and motts of *Lathyrus* species in Oceania do not significantly differ to pea, but these species were never compared in Europe. Narrow-leaved lupin (*Lupinus angustifolius*), yellow lupin (*Lupinus luteus*) and white lupin (*Lupinus albus*) tend to lead to lower grain yields and grain protein yields than pea in all regions, but only a limited number of experimental data are available for these species. Other *Lupinus* and *Vicia* species (except faba bean) were compared only with pea in Oceania. Among these species, *Vicia narbonensis* and *Vicia sativa* are the most productive.

Conclusions

Our study sheds new light on grain yields and grain protein yields of a wide diversity of legumes species. Results reveal that faba bean may be targeted as candidate protein crop for European agriculture. There is much uncertainty on soybean productivity levels. Further agronomic experiments are needed to compare soybean with other legume species in Europe, especially *Lathyrus*, *Lupinus* and *Vicia* species.

Acknowledgments

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Introduction

Faba bean (Vicia faba L.) kernels (dehulled beans) can be air-classified (Cloutt et al., 1986) into bean protein- and starch-concentrates (BPC and BSC, respectively). The BPC is desired by manufacturers of farmed salmon feed, and the BSC has utility as animal feed. BPC is an excellent aquaculture feed adjunct with feed conversion rates matching or exceeding current formulations and improved fish fillet-yield, processing quality and shelf life (www.beans4feeds.net/projectreports). However, the BSC fraction represents the bulk (80% by weight) of the processed kernel by-product, and its current value as an animal feed is insufficient to justify extensive investment in a large scale air classification facility in Scotland. The commercial efficacy of faba bean air-classification may be increased if individual beans were to have a higher protein concentration, and/or if higher value routes are developed for the BSC, e.g. neutral spirit production (Walker et al., 2015). Here we report on: efforts to improve the protein content of individual faba beans, and; 2) the financial savings and mitigated environmental costs which may be made by cropping faba beans in Scotland to meet the demand of Scottish salmon farms. Approximately 500 k ha of Scottish farmed land (excluding grassland) is arable but < 3% is used to produce plant protein. Current demand for faba beans for farmed salmon in Scotland is estimated at 160 Gg y\(^{-1}\). With average faba bean yields of 4 Mg ha\(^{-1}\) y\(^{-1}\), around 40 k ha or one twelfth of Scottish arable land would be required.

Materials and Methods

Germplasm collection screening: To identify faba bean lines that may be suitable resources for high protein bean breeding, 400 accessions from the James Hutton Institute faba bean germplasm collection were cultivated in field in Tygan-covered tunnels in 2012 and 2013, under conditions of no added nitrogen (N) and pollinator exclusion, and were self-pollinated (by hand). Recombinant Inbred Line (RIL) screening: to help develop a platform for marker assessed breeding of faba beans for high individual bean protein content, a Recombinant Inbred Line (RIL) population (150 F\(_9\) lines derived from a cross between Vicia faba ssp paucijuga (an Afghan landrace) x cv ‘Optica’) was grown in the same conditions as the germplasm collection in 2012 and 2013. Ecological Economics: the financial and environmental costs of faba bean cultivation to serve Scottish farmed salmon production were made according to on-line resources indicated in the References section.

Results and Discussion

Germplasm collection: 239 of the lines (plus 6 Fuego controls) provided sufficient seed for analysis. Of these, seven lines were identified as having consistently high protein values in both years (Table 1). RIL screening: There is significant variation among the RIL population for individual bean protein content (Fig. 1), and other important traits (e.g. yield, biological N fixation). Recent advances in bean genotyping have identified 845 single nucleotide polymorphism (SNP) markers (Webb et al. 2016), to delineate the six chromosomes of faba bean (2n = 2x = 12; genome size ~13000 Mb). Also, comparative gene mapping with model legume Medicago truncatula (barrel medic), has shown a high levels of genetic synteny with faba bean. Our strategy is thus to use KASP™ genotyping (Webb et al. 2016), to allow the genetic mapping of important faba bean genes without the requirement for a sequenced faba bean genome.

Table 1. Seven accessions from the faba bean reference collection which gave consistently high individual bean protein contents (2012-13; 30-37%), and yields to justify onward breeding.

<table>
<thead>
<tr>
<th>Accession</th>
<th>2012</th>
<th>2013</th>
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</thead>
<tbody>
<tr>
<td>Early Longpod</td>
<td>30.4</td>
<td>32.7</td>
</tr>
<tr>
<td>ILB287</td>
<td>30.4</td>
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<tr>
<td>Martock Bean</td>
<td>31.9</td>
<td>35.3</td>
</tr>
</tbody>
</table>
Figure 1. Data from an F$_2$ population ranked by increasing seed protein content (% dry mass; 2013 data) for RILs of a cross between $Vicia$ 
$faba$ ssp $paucijuga$ (an Afghan landrace) × cv ‘Optica’.

Ecological Economics: Considering the faba bean area required to meet the demand by Scottish farmed salmon producers (40 K ha): faba bean can deliver 60-100 kg ha$^{-1}$ of N in post-harvest in-field residues (Iannetta et al., 2013), offsetting N fertiliser requirements up to 90% for a following spring barley crop, or save £950 k y$^{-1}$ in fertiliser costs (at £26.40 ha$^{-1}$), which is doubled by N-fertiliser avoided by growing faba bean as it requires no N fertiliser. The N-fertiliser offset may also be accounted as a carbon footprint reduction of 97 Gg CO$_2$-equivalent for a 2-year bean-to-barley cropping sequence (Hillier et al., 2009), and equivalent to planting 25 k trees annually. Financially, 160 Gg of whole beans may be valued at £215 t$^{-1}$, or £9.5 million. However, considering beans as 1:3:1 hulls:BPC:BSC with respective values of ca. £70, £600 and £350 t$^{-1}$, means that the total values are £2.4-, £19- and £25.7-million, respectively, or 5 times the whole bean value.

Conclusions
Increasing the cultivation of faba beans demands the development of more profitable markets for them, and as the value of bean components is 5x greater than that of whole beans, our approach may help increase the commercial value of faba bean and encourage uptake of legume supported crop systems.

Acknowledgements
The scientific research reported here is supported by funding from: the Scottish Government; the EU funded project Legume Futures (www.legumefutures.eu), and the Technology Strategy Board co-funded project Beans4feeds (www.beans4feeds.net) (TSB101096). The industrial partners of beans4feeds are EWOS Ltd., BioMar Ltd., Limagrain UK Ltd., Marine Harvest (Scotland) Ltd. and Harbro Ltd. The academic partners are the Universities of Stirling, Aberdeen, and St. Andrews, Scotland’s Rural College and the James Hutton Institute. Thanks are also extended to Roger Vickers and Becky Ward of the Processors and Growers Research Organisation (PGRO), and Dr. David Styles of the University of Bangor.

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ORGANIC LENTIL PRODUCTION – THE DEVELOPMENT OF AN INTERESTING NICHE IN SWITZERLAND

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Introduction

Lentil (Lens culinaris Medikus) belongs to the legume family and is grown as seeds for the human diet, and the straw can be used for animal feed. Lentil is considered one of the oldest grain legume crops, domesticated in ancient times (Cubero et al., 2009). Although its main cropping areas are outside of Europe (India, Canada), lentil is grown in some European countries on more than 10 000 ha (Turkey, Spain, France; FAO, 2016). The area in Switzerland cropped with lentil is estimated to be less than 50 ha. To meet the increasing demand of consumers, importation of lentil seeds increased from 20 04 (1300 t) by 600 t in the year 2014 in Switzerland (FCA, 2016).

Due to the comparatively low need for nutrients, lentil is suitable for extensive cropping systems and marginal soils, but as a consequence of its poor early vigor, competition with weeds is a major handicap for successful production in organic farming. Additionally, poor resistance to lodging can lead to problems at the harvest, causing additional efforts for eliminating stones and soil particles before selling. In order to deal with both challenges, lentils often are grown in mixtures.

The aim of this project is to establish an organic lentil production in Switzerland by conducting various trials in several regions with different objectives.

Materials and Methods

The project was initiated in 2011 and has continued since then with various small plot experiments and strip trials in three different provinces of Switzerland. At the beginning, different companion plants (spring oat, spring wheat, buckwheat, and camelina) were investigated, and since 2013 different cultivars have been compared. Since 2014 fallseeded cultivars are compared with spring-seeded cultivars. In order to transfer knowledge and encourage farmers to share competences, field days and trips to other producers, also in neighboring countries, are organized. Collaboration with a farmers’ cooperative allows slowly to develop competences in the processing of the harvested material and to market the product in common in organic stores.

Results and Discussion

Depending strongly from year and companion plant, yield varied between 800 and 1500 kg ha⁻¹ and differences among cultivars were observed (Figure 1). Most of the tested companion plants helped considerably to suppress weeds and decrease lodging, and as a consequence to facilitate harvest. At the moment, however, no single species can be recommended as the best companion plants for all conditions. Among other factors, available machinery or soil properties are important for successful establishment of mixtures with lentils. Oat may compete well with weeds and due to its short plant length is well suited for growing with lentils, though it causes additional efforts in the cleaning process. In most cases, land equivalent ratios were > 1. Most of the fall-sown cultivars survived winter. Flowering of fall-seeded cultivars started 27 days earlier than spring-seeded cultivars, but yield was lower and variability increased (Table 1).
### Table 1. Beginning of flowering (day), yield (kg ha\(^{-1}\) at 8% H\(_2\)O) and thousand seed weight (g) of nine lentil cultivars seeded in fall or in spring and managed according to organic farming practice (Zurich, 2015)

<table>
<thead>
<tr>
<th></th>
<th>Beginning Flowering (Day)</th>
<th>Yield (kg ha(^{-1}) at 8% H(_2)O)</th>
<th>Thousand Seed Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Fall Seeded</td>
<td>130.6</td>
<td>123.7</td>
<td>137.3</td>
</tr>
<tr>
<td>Spring Seeded</td>
<td>157.1</td>
<td>155.0</td>
<td>161.3</td>
</tr>
</tbody>
</table>

### Conclusions
Lentil production in conditions of organic farming in Switzerland is possible. In line with Gruber et al. (2012), no single strategy for controlling weeds can be recommended. Whether fall seeding of lentil is a possibility to bypass water shortage in summer has to be verified in subsequent trials. Increasing area planted with lentils shows the interest of farmers and necessity to increase knowledge for lentil growing.

### Acknowledgements
Funding by BioSuisse and Fondation Sur-La-Croix, breeders for providing seeds, as well as inspiring discussions with various persons and the cooperativeness of the farmers where the trials were carried out, is gratefully acknowledged.

### References
LEAF DISEASES – THE EMERGING PROBLEM IN THE SOWINGS OF FABA BEAN IN LATVIA

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Introduction
Cultivation of faba bean (Vicia faba L. var minor) has become more popular in Latvia, but along with enlargement of sowing area, also potential yield losses increase due to development of diseases. Chocolate spot, caused by Botrytis spp., is considered as the most harmful disease around the world (Stoddard et al., 2010), but other diseases are important (Stoddard et al., 2010; El-Hai, 2015). The aim of this study is to determine the most important faba bean diseases in Latvia and identify causal agents.

Materials and Methods
Diseases were determined and causal agents identified in a multi-factorial trial in the Research and Study farm of Latvia University of Agriculture. The severity (0–9 point scale) of diseases on the leaves was assessed every week after appearance of first symptoms. The development of diseases on the pods was determined once, shortly before harvesting, and in this case only incidence was noted. The AUDPC (area under disease progress curve) was calculated. Visually damaged tissues of leaves, pods and faba grains were placed on the PDA (potato dextrose agar) and pure cultures were obtained. Pathogens were identified on the basis of colony morphology and DNA sequences.

Results and Discussion
First symptoms (large, diffuse, dark lesions) of Alternaria/Stemphylium leaf blotch and chocolate spot were found on the leaves shortly before flowering, and rust (caused by Uromyces viciae-fabae) appeared 2 weeks later. Alternaria/Stemphylium leaf blotch dominated on the leaves during all periods of evaluation, the average severity of this disease being 2.7 points, but chocolate spot reached only 1.7 points, and the severity of rust did not exceed 0.5 points. The total impact of leaf diseases during all seasons of vegetation was shown as AUDPC (Figure 1). Strong infection of pods was observed before harvested, when the incidence of diseases reached nearly 80%, but on the pods prevailed chocolate spot, not only as blotches, but also as sclerotia – on average two sclerotia per pod. Symptoms of diseases were observed also as blotches on 20% of grains.

Alternaria spp. and Stemphylium spp. were found in all parts of plants – leaves, pods and grains, and this is an unexpected result, because Botrytis fabae was considered as the main pathogen of faba bean in most trials around the world. Identification of Alternaria and Stemphylium species was continued. Some morphological differences (amount and layout of sclerotia, texture and colour of mycelium) among Botrytis isolates were observed. Molecular analyses confirmed that all three species of Botrytis – B. fabae, B. cinerea and B. fabiopsis were recognized in our trials. Similar results were obtained by Zhang and others (Zhang et al., 2010). B. fabae and B. cinerea were found in all parts of plants, but B. fabiopsis only on the leaves. Interrelations among Botrytis species and pathogenicity differences are not clear yet, and need further investigation.
Conclusions
Diseases are an important risk factor for cultivation of faba beans in Latvia. Alternaria/Stemphylium leaf blotches and chocolate spot were the most important diseases. All three species of Botrytis, namely B. fabae, B. cinerea and B. fabiopsis, were recognized, but further analyses are necessary to clarify harmfulness of diseases and identify species of pathogens.

References
PRE-ANTHESIS NITROGEN USE EFFICIENCY OF SPRING BARLEY CULTIVARS GROWN WITH MIXED MINERAL AND ORGANIC NITROGEN SOURCES

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Introduction
There is currently a drive to increase the use of legumes in European agriculture, both for their products (forage and grain) and as a source of biologically fixed N for following crops. However, the supply of N from legumes may be insufficient due to either low levels of fixation or the N availability not being synchronised with crop demand. One method to mitigate this shortfall is to augment legume-derived N with targeted application of mineral N fertilisers.

Nitrogen use efficiency (NUE), the yield per unit of N supply, has been steadily increasing over the last 75 years due to plant breeding programmes (Bingham et al., 2012). However, these programmes have been conducted under conditions of plentiful fertiliser N supply. Whether the improvements in NUE are maintained when plants are grown with a mixed supply of mineral and organic (legume) N sources is unknown.

This experiment aims to study the pre-anthesis NUE of different cultivars of spring barley supplied with either mineral or mixed mineral and organic N sources. The main objectives were to determine how the yield and NUE of each cultivar differs when grown on mineral or mixed N sources, and whether any differences were related to the year of introduction.

Materials and Methods
Fifteen cultivars of spring barley (Hordeum vulgare L) covering a range of breeding years, from 1931 to 2006 were grown outside in pots under three fertiliser treatments: N supplied as NH₄NO₃ in solution at a rates of 0 (T0) or 60 kg ha⁻¹ of N (T60), and 30 kg ha⁻¹ of N as NH₄NO₃ plus red clover residues equivalent to 30 kg ha⁻¹ of N (T3030). The experiment was set out according to a split-plot design, with five replicates (blocks). The treatments were randomized within each block and the cultivars randomized within treatments. A general nutrient solution was applied 10 days and 6 weeks after sowing, P and K fertilisers were added at sowing and fungicide was applied according to local practice. Pots were harvested at mid/late ear emergence. Aboveground biomass and nitrogen contents were measured. NUE was calculated by estimating soil N supply as N offtake in T0 plants plus any fertiliser N applied.

Results and Discussion

The pre-anthesis yield advantage of T3030 over T60 was negative in most cases but there was considerable variation between cultivars (Figure 1). The only positive yield advantage was about 1.5 g per pot, compared to the greatest negative value of -3.3 g per pot. Given that the mean yield per pot was about 12 g, these represent a range of +15 to -30%. NUE was generally higher in T60 than in T3030, with only one cultivar having higher NUE in T3030. Again, there were considerable differences between cultivars although the range of NUE values was greater in T60 than in T3030. Neither the differences in yield nor NUE were related to year of introduction.
Conclusions
Most cultivars of spring barley tested had higher yields and NUE when grown on mineral N fertiliser rather than on a mix of mineral fertiliser plus legume residue. The relative performance of both yield and NUE on mineral versus mixed N sources showed considerable variation between cultivars. These results indicate that the highest performing cultivars under conditions of high N fertiliser use may not be the best to use in a scenario where a substantial proportion of the N supply is legume derived. Furthermore they suggest that breeding targeted at improving the use of legume N by following crops is a worthwhile goal, given the substantial levels of variation reported here.

Acknowledgements
Thanks to Camille Clipet, Vicky Munro, Jakub Olewski and Derek Simpson for technical assistance.

Reference
FABA BEAN YIELD AND YIELD COMPONENTS

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2 Research and Study farms “Peterlauki” of Faculty of Agriculture, Latvia University of Agriculture

Introduction

Faba bean (Vicia faba) can be included among the well known but neglected crops in Latvia. Nowadays cultivation of faba bean is promoted by the Common Agricultural Policy (CAP) of the EU demanding crop diversification and greening. Latvian research on different aspects of faba bean growing ceased 40 years ago, but even researchers from other countries report that still little is known about growth and development of this crop (Lopez-Bellido et al., 2005). The aim of this paper was to report yield and yield components of faba bean depending on cultivar, sowing rate and fungicide application.

Materials and Methods

A three-factor field trial with faba bean was arranged at the Research and Study Farm “Peterlauki” (56° 32’ N, 23° 43’ E) of the Latvia University of Agriculture in 2015. Factor A was three cultivars (‘Laura’, ‘Boxer’, ‘Isabell’), factor B was three sowing rates (30, 40 and 50 germinable seeds per m²), and factor C was fungicide application (C1 – without fungicide, C2 – fungicide boscalid (267 g kg⁻¹) + pyraclostrobin (67 g kg⁻¹) at the rate 1.0 L ha⁻¹ at the start of flowering stage). The soil at the site was a well-cultivated Endocalcaric Abruptic Luvisol (Cutanic, Hypereutric, Raptic, Siltic, Protostagnic, Epiprotovertic), silt loam. Growing practices followed the recommendations for the area. Yield was accounted directly on harvesting all plots and recalculated on 100% purity and 14% moisture. Yield components (number of pods per plant, number of seeds per pod, number of seeds per plant) were determined from 10 randomly chosen plants per plot, and 1000 seed weight, g, was determined from harvested yield according to standard methods. Analysis of variance was used for data processing and the Bonferroni test was used for comparison of means. The vegetation period in 2015 was characterized by cool temperatures and sufficient moisture in the first half, but in August, during pod and seed filling, it was hot and without rain.

Results and Discussion

Average yield of faba bean depended on all three investigated factors significantly (P<0.05). Despite the high yield potential of all three cultivars, seed yield of ‘Isabell’ was significantly less than that of two others (Table 1). Environment conditions mainly govern seed yield (Graf & Rowland, 1987; Lopez-Bellido et al., 2005) and obviously conditions in 2015 gave more possibilities for higher yield formation for genotypes ‘Boxer’ and ‘Laura’. Fungicide application increased yield by a small but significant (P<0.05) amount (0.17 t ha⁻¹), and the only yield component increased by fungicide treatment was 1000 seed weight (Table 1).

Table 1. Average yield and values of yield components of faba bean depending on cultivar, sowing rate and fungicide application in 2015

<table>
<thead>
<tr>
<th>Investigated Factors</th>
<th>Yield, t ha⁻¹</th>
<th>Number Of Pods Per Plant</th>
<th>Number Of Seeds Per Pod</th>
<th>Number Of Seeds Per Plant</th>
<th>1000 Seed Weight, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laura</td>
<td>5.99 a</td>
<td>12.00 b</td>
<td>3.02 a</td>
<td>36.3 a</td>
<td>553 b</td>
</tr>
<tr>
<td>Boxer</td>
<td>6.10 b</td>
<td>10.95 a,b</td>
<td>3.14 b</td>
<td>34.5 a</td>
<td>593 a</td>
</tr>
<tr>
<td>Isabell</td>
<td>5.57 a</td>
<td>10.53 c</td>
<td>3.58 b</td>
<td>37.6 a</td>
<td>532 a</td>
</tr>
<tr>
<td>Sowing Rate, Germinable Seeds m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>5.52 a</td>
<td>13.52 c</td>
<td>3.24 a</td>
<td>43.7 a</td>
<td>548 a</td>
</tr>
<tr>
<td>40</td>
<td>6.01 a</td>
<td>10.90 a</td>
<td>3.27 a</td>
<td>35.4 a</td>
<td>563 a</td>
</tr>
<tr>
<td>50</td>
<td>6.13 b</td>
<td>9.06 a</td>
<td>3.23 b</td>
<td>29.2 a</td>
<td>567 a</td>
</tr>
<tr>
<td>Fungicide Application</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F0</td>
<td>5.80 b</td>
<td>11.10 a</td>
<td>3.23 a</td>
<td>35.8 a</td>
<td>554 a</td>
</tr>
<tr>
<td>F1</td>
<td>5.97 a</td>
<td>11.23 c</td>
<td>3.27 b</td>
<td>36.4 a</td>
<td>565 b</td>
</tr>
</tbody>
</table>

Significantly different (P<0.05) means are labelled with different letters in superscript.
The choice of sowing rate, which is the main cause of final plant density, especially for spring crops, mainly affects seed yield and most of yield components of faba bean (Graf & Rowland, 1987; Lopez-Bellido et al., 2005). In our experiment, yield also increased with increasing sowing rate (Table 1). Number of seeds per pod is a stable and genetically determined yield component and did not depend on sowing rate in our experiment, confirming earlier findings. The number of pods per plant and number of seeds per plant were highly dependent on sowing rate and decreased with sowing rate increase. This agrees with results of other investigations that smaller number of plants are compensated by more pods per plant and seeds per plant (Graf & Rowland, 1987; Lopez-Bellido et al., 2005). We found that 1000 seed weight increased with sowing rate increase, and this result is in contradiction with other findings. The explanation could be that in hot and overly dry conditions during pod and seed fill in 2015, plants in higher density stands had to fill less pods and seeds than those in thinner stands.

Conclusions
Faba bean yield on average was high and was substantially affected by all three investigated factors. Yield components substantially varied depending on cultivar (except number of seeds per plant) and sowing rate (except number of seeds per pod); fungicide application increased only 1000 seed weight. Further investigations are needed to choose sowing rate between 40 and 50 germinable seeds m\(^{-2}\) and to specify fungicide application pattern.

References
THE SURVIVAL OF THE COMMERCIAL INOCULANT IN WHITE CLOVER AND LUCERNE

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Introduction

For maximum $N_2$ fixation to occur, legumes must be nodulated by efficient strains of rhizobia. When resident naturalised populations of rhizobia are high, the need for commercial inoculant has been questioned (Lowther & Kerr, 2011). This research investigated the survival of the commercial inoculant for white clover and lucerne in the field in New Zealand. The survival of the commercial inoculants RRI128 for lucerne ($Medicago sativa$ L.) and TA1 for white clover ($Trifolium repens$ L.) was investigated at two Lincoln University dryland sites. The aim was to quantify the duration of survival of the commercial inoculants for lucerne and white clover in the presence of naturalized strains.

Materials and Methods

Lucerne and white clover were gown at Lincoln University Field Research Centre as pure swards in neighbouring paddocks that had been previously been sown to lucerne and white clover, respectively. The lucerne paddock was sown in November 2010 and the white clover in December 2014. The lucerne paddock was inoculated with RII128 and the white clover with TA1. The lucerne paddock had two inoculant preparations, peat slurry and a seed coat. TA1 was applied to the white clover in a seed coat. At each sampling, 10 – 20 lucerne plants were extracted from both the peat and coated seed treatments. Samplings occurred in January 2011, January 2014 and January 2015. For white clover 10 plants were dug up every 8 weeks after sowing for 8 months. Both the lucerne and white clover all plants showed nodulation of the roots, so 1-10 nodules were selected and sterilized. In total, ~50 nodules were collected for each treatment, at each sampling. Rhizobia were recovered from the nodules. DNA extraction and ERIC PCR of bacterial DNA was also carried out as described in Wigley et al. (2015). The presence of the commercial inoculant was confirmed by nodules that had the same ERIC banding pattern as the commercial inoculant. This was confirmed by 16S rRNA gene sequencing of the bacteria in the nodules with the same banding pattern as the commercial inoculant.

Results and Discussion

The percentage of nodules containing the commercial inoculant for lucerne and white clover changed over time (Table 1). In 2011, two months after sowing, RRI128 was dominant and recovered from 40% of the nodules plants grown from coated seed (n=20 nodules). In 2014, 3 years after sowing, RRI128 was also most common in the nodules from peat and coated seed plants at 64% (n=34) and 48% (n=29). Overall the occupancy of RRI128 in the nodules had increased in both the peat (22%; n=11 vs 64%; n=34) and coated (40%; n=20 vs 48%; n=29) seed treatments from 2011 to 2014. In 2015, four years after sowing, the commercial inoculant for lucerne was still the most common genotype found in the peat seed plants at 61% (n=31). In the nodules of coated seed plants the commercial inoculant was only found in 13% (n=5) of the nodules. The commercial inoculant for lucerne has also been found to be effective at increasing plant growth. Black & Moot (2013) and Berenji et al. (2015) found that when lucerne was sown in soil that had not previously been sown in lucerne the application of a peat inoculant doubled first or second year yield compared with a bare seed control. This suggests it had competed with the naturalised strains in the soil for nodule occupancy. In contrast, for white clover, 2 months after sowing TA1 was found in only 8% of the nodules collected (n=4). At 4 months after sowing TA1 was found in 24% of the nodules and eight months after sowing TA1 was found in 8% of the nodules. Brockwell et al. (1975) also found that when seed inoculated with TA1 at a rate of 135 rhizobia per seed was sown into a soil containing 10,000 naturalised rhizobia per gram, less than 10% of nodules were

<table>
<thead>
<tr>
<th>Lucerne</th>
<th>2011</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coated Seed</td>
<td>40</td>
<td>48</td>
<td>13</td>
</tr>
<tr>
<td>Peat Seed</td>
<td>22</td>
<td>64</td>
<td>61</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>White Clover</th>
<th>Feb 2015</th>
<th>April 2015</th>
<th>August 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8</td>
<td>24</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 1. Percentage of the commercial inoculant observed in isolates recovered from the nodules of lucerne plants treated with lime coat and peat inoculant and white clover at Lincoln University, New Zealand.
occupied by TA1. It appears that TA1 was not competitive or persistent in its ability to nodulate white clover plants, and that it is easily out-competed by naturalised strains in the soil. This contrasts with the commercial strain for lucerne which survived and persisted for over four years.

Conclusions
The commercial inoculant for lucerne was able to persist four years after sowing when applied as a peat slurry, whereas the commercial inoculant for white clover was present in only 8% of nodules 8 months after sowing.

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WHITE LUPIN & TRITICALE INTERCROPS: NEW FINDINGS AFTER THREE YEARS OF PLOT TRIALS

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Introduction
The agricultural cooperative Terrena includes 22,000 farmer members. As part of its Ecologically Intensive Farming (EIF) strategy, Terrena aims to increase the protein autonomy of farms. White lupin is a grain legume that is well adapted to Terrena’s territory, so the cooperative has developed a complete value chain, from seed breeders to grain processing facilities for lupin production. Today the market (animal and human nutrition) needs more lupin, but farmers are rather reluctant to increase the acreage of this risky crop. Hence we tested associating lupin with triticale as a companion crop in an agro-ecological solution during 7 years (2008–2016) with the help of farmers and agronomic institutes. The first goal was to find a solution for weed control, because lupin can be considered as an orphan crop with no efficient registered herbicide. Fungal diseases, light competition and shape of the two crops were studied.

Materials and Methods
Agronomic Department of Terrena (20 engineers and technicians) managed each year statistical micro-plot trials. These trials are based on i) four repeats of each tested treatment; ii) on several control plots; iii) statistical alpha-map - Latin square map. The microplot size is generally 2 × 10 m². Each year, approximately 14000 microplots are managed.
Terrena’s Agronomic Department is certified “Good Practices of Experimentation” by the French government authorities. Sowing, spraying, fertilizing and harvesting are done with specific trial machinery. Technical notations and observations are realized all along the crop growth by agronomists.
Each year, these trials are visited by farmers so that they can benefit from the novel agronomic knowledge.
Regarding lupin trials: one trial compares solo lupin (Clovis variety – complete herbicide protection) to lupin + triticale (Clovis + Ragtac – without any herbicide), during 3 campaigns, in 3 different “soil and climatic” (and disease pressure) conditions.
In 2015, another trial solo lupin (Clovis variety), with herbicide KERB FLO 1,875 L/ha, was compared to lupin associated with 3 different companion plants (without any herbicide) : 1) leguminous (clover + vetch), 2) wheat (variety Rubsiko) and 3) triticale (Ragtac variety). The main weed in the microplots was ryegrass. Biomass samples have been evaluated in Terrena’s certified laboratory. This poster presents some results of 2013, 2014 and 2015 lupin trials.

Results and Discussion
Specific technical knowledge has been obtained and transferred to farmers: best practices to get success with sowing (in one single operation) and seed germination, disease management (one fungicide at early flowering stage of lupin) and best combine settings.
The average yield in 2013–2015 was 2.7 t ha⁻¹ (lupin) + 2.5 t ha⁻¹ (triticale). Even including cost for grain separation (€15 t⁻¹), associated lupin could be a competitive solution over solo lupin (2.5 t ha⁻¹): economical margin reaches 1022 € per hectare, as is obtained from 8.5 t ha⁻¹ of wheat or 3.5 t ha⁻¹ of oil seed rape.
The beneficial “lupin + triticale” intercrop has been chosen and some technical knowledge has been transferred to farmers. This EIF solution is now proposed to farmers: in 2016, Terrena farmer members will harvest around 5500 ha (+50% compared to 2015), of which 250 ha are the species mixture. In 2015, however, new problems appeared (particularly a triticale disease) and led to follow up with extra field and lab trials.

Reference
PRODUCTION OF EARLY MATURING CULTIVARS OF SOYBEANS (GLYCINE MAX (L.) MERR.) IN NORTHWESTERN POLAND

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Introduction
Currently, the four biggest soybean producers are the USA (51%), Brazil (19%), Argentina (10%) and China (9%). Given the areas, soybean is the fourth most important crop (93 million ha) after wheat, maize and rice (http://faostat3.fao.org). World average seed yield amounts to 2.3 t ha⁻¹, in Poland 1.6 t ha⁻¹ (Bujak & Frant, 2009). Soybean production in a temperate climate can be profitable but unstable, due to the high thermal and water requirements, which are often unfavorable. Soybean meal (SBM) provides valuable feed with balanced, high quality protein content of 35–45% and oil of high nutritive value (19–23%) (Jezierny et al., 2010). The soybean crop also plays a beneficial role in crop rotation, leaving good habitat for the following crop. Soybean contribution in the crop structure should grow according to the agri-environmental programs on greening and on increasing the contribution of legumes for protein production in conventional way. For this purpose, the project stared by choosing from the European list some early maturing cultivars for farming in northwestern Poland. This is the first in the history of soybean as a wide campaign in this region.

Materials and Methods
In the framework of cooperation (2015–2018) between the UTP University of Science and Technology in Bydgoszcz and LECHPOL Company in Szubin, the field trials started in 2015 to determine the suitability of 16 soybean cultivars for growing in Kujavia-Pomerania province (53°04′ N, 18°29′ E). Sowings took place in two locations, at the Research Station of the Faculty of Agriculture and Biotechnology UTP Mochełek on soil suitable for rye, and at the farm belonging to LECHPOL in Grocholin, on soil of wheat class. Certified seed of 16 conventional cultivars of soybeans were obtained from the European breeders from 6 countries (Table 1). All cultivars belong to the group of very early maturing, so-called. "000".

Results and Discussion
A severe drought in July 2015 met the soybean at the flowering stage. Rainfall from April to August was 144 mm in Mochełek and 203 mm in Grocholin, while normally it amounts to 296 mm in this region. This means that precipitation was about 30–50% less than the average, while the temperature in August exceeded 3°C above average. In such conditions, the tolerance to summer drought was detected. The most drought-resistant was cv. 'Layma' from Ukrainian Breeding AgroYoumis. On the weaker soil 'Layma' obtained the highest yield of all cultivars, in turn, cv. 'Gallec' from the Swiss Breeding Delley had a relatively high thousand seed weight, which also explains its high yield. Cultivar 'Aldana' from HR Strzelce had even larger seeds and a yield of 1.72 t ha⁻¹. These three cultivars produced the highest yield on the weaker soil, along with 'Amarok' and 'Merlin' are the fifth top yielding. On the soil of wheat class (Grocholin) in order of the best yields, cultivars were 'Merlin' (1.88 t ha⁻¹), 'Amarok' (1.77 t ha⁻¹), 'Aldana' (1.60 t ha⁻¹), 'Mavka' (1.58 t ha⁻¹) and 'Layma' (1.57 t ha⁻¹). It is noteworthy that in both locations, four of the same cultivars were among the top yielding. In Central Europe, soybean cultivation is still quite new and breeding of early maturing soybean varieties adapted to various weather conditions has just started (Zimmer et al., 2016).
Table 1. Yield, protein and oil content of 16 European cultivars planted in Kujavia-Pomerania, Poland, 2015

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Origin</th>
<th>TSW (g)</th>
<th>Seed Yield (At 12% Moisture)</th>
<th>Protein (%)</th>
<th>Oil (%)</th>
<th>Harvest Date</th>
<th>Earliness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mochelek</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annushka</td>
<td>UA</td>
<td>109</td>
<td>1.38</td>
<td>1.40</td>
<td>39.7</td>
<td>20.9</td>
<td>3.09</td>
</tr>
<tr>
<td>Violetta</td>
<td>UA</td>
<td>154</td>
<td>1.27</td>
<td>1.43</td>
<td>37.1</td>
<td>22.6</td>
<td>18.09</td>
</tr>
<tr>
<td>Aldana</td>
<td>PL</td>
<td>182</td>
<td>1.72</td>
<td>1.60</td>
<td>43.2</td>
<td>20.3</td>
<td>7.09</td>
</tr>
<tr>
<td>Alligator</td>
<td>FR</td>
<td>154</td>
<td>1.42</td>
<td>1.04</td>
<td>44.2</td>
<td>19.1</td>
<td>18.09</td>
</tr>
<tr>
<td>Amarok</td>
<td>DE</td>
<td>136</td>
<td>1.58</td>
<td>1.77</td>
<td>38.7</td>
<td>21.7</td>
<td>16.09</td>
</tr>
<tr>
<td>Gallec</td>
<td>CH</td>
<td>150</td>
<td>1.53</td>
<td>1.37</td>
<td>43.6</td>
<td>19.8</td>
<td>16.09</td>
</tr>
<tr>
<td>Gallice</td>
<td>CH</td>
<td>150</td>
<td>1.77</td>
<td>1.16</td>
<td>45.0</td>
<td>19.2</td>
<td>16.09</td>
</tr>
<tr>
<td>Layma</td>
<td>UA</td>
<td>129</td>
<td>1.90</td>
<td>1.57</td>
<td>34.4</td>
<td>23.3</td>
<td>7.09</td>
</tr>
<tr>
<td>Lissabone</td>
<td>AT</td>
<td>139</td>
<td>1.48</td>
<td>1.16</td>
<td>44.9</td>
<td>19.3</td>
<td>16.09</td>
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<tr>
<td>Mavka</td>
<td>UA</td>
<td>154</td>
<td>1.32</td>
<td>1.58</td>
<td>43.6</td>
<td>20.2</td>
<td>18.09</td>
</tr>
<tr>
<td>Merlin</td>
<td>AT</td>
<td>116</td>
<td>1.56</td>
<td>1.88</td>
<td>41.1</td>
<td>20.6</td>
<td>7.09</td>
</tr>
<tr>
<td>Petrina</td>
<td>FR</td>
<td>159</td>
<td>1.55</td>
<td>1.35</td>
<td>41.5</td>
<td>20.6</td>
<td>18.09</td>
</tr>
<tr>
<td>Protina</td>
<td>FR</td>
<td>154</td>
<td>1.18</td>
<td>1.50</td>
<td>45.0</td>
<td>19.1</td>
<td>18.09</td>
</tr>
<tr>
<td>Senator</td>
<td>FR</td>
<td>156</td>
<td>1.52</td>
<td>1.30</td>
<td>41.0</td>
<td>20.6</td>
<td>16.09</td>
</tr>
<tr>
<td>Augusta</td>
<td>PL</td>
<td>116</td>
<td>1.17</td>
<td>0.96</td>
<td>42.8</td>
<td>19.8</td>
<td>07.09</td>
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<tr>
<td>Klaxon</td>
<td>FR</td>
<td>156</td>
<td>1.30</td>
<td>1.42</td>
<td>37.0</td>
<td>22.4</td>
<td>18.09</td>
</tr>
</tbody>
</table>

Conclusions
Optimizing and further development of European conventional soybean programs will be welcome to develop a strategy for creating a northeastern European soy cultivation area with adapted, high-yield cultivars.

References
CROPS PROVIDING PROTEINS FOR FOOD: A REVIEW

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Introduction
There is an increasing debate about the importance of plant-based proteins and the diversification of protein sources for human nutrition (De Boer & Aiking, 2011). Plant-based proteins originate in several botanical families but are mainly concentrated in legumes. Several scholars have been interested in legumes because of their role as a source of food, feed and bioenergy/biomaterials but also because of the agro-ecosystem services they provide (Nemeecck et al., 2008; Voisin et al., 2014; Gan et al., 2015). Despite their importance, legume consumption and production are declining worldwide as a source of food (Ranalli 1995; Voisin et al., 2014). Only soybean area is continuously increasing, linked to the intensification of livestock production (Voisin et al., 2014). In the literature, according to the number of papers dealing with legumes and the stakes for research, these crops are often considered as a group or studied at the single crop level. The goal of this paper is to provide a systematic review of the diversity of crops providing proteins for human nutrition, in terms of worldwide distribution and production, dynamics, place in the cropping systems and nutritional or anti-nutritional characteristics.

Materials and Methods
We considered as crops providing proteins for food those species having more than 15% of proteins and that are or can be part of human diet after processing: pulses (common, 26 species and minor, 9 species), other legumes (2 species) and other crops (12 species including bacteria). Geographic distribution and productivity of these crops were assessed from the FAOSTAT database (1990—2014) and their spatial distribution represented using ArcGis® software for 2014. The place of these crops within the cropping systems was assessed from literature. Finally, the main nutritional and anti-nutritional characteristics of the crops were assessed from literature and from official databases, e.g. USDA national nutrient database for standard reference.

Results and Discussion
On the 49 species considered in the analysis, data on geographical distribution, crop production and presence of anti-nutritional were unavailable only for some minor pulses. The 2014 worldwide distribution of these crops is variable, but show that representatives can be grown everywhere, though core areas are the Middle East and Mediterranean areas for several common pulses and Africa for minor pulses (Figure 1). The other legumes and other crops are better distributed except for quinoa (Andean countries), hemp (Eastern/Western Europe) and chia (Central/Southern America).

![Figure 1](source: Institut Polytechnique LaSalle Beauvais and FAOSTAT database (2014)).

These species are mainly herbaceous but also shrub (e.g. pigeon pea) or trees (e.g. cashew), and include some adapted to intercropping or mixed cropping. Legumes are often in symbiosis with Rhizobia and can precede cereals as a fertility-building crop.
Table 1. Synthesis of average nutritional characteristics (standard deviation) of some crops providing proteins. PA means Phytic Acid, T Tannins, S Saponins, TI Trypsin Inhibitors, CI Chymotrypsin Inhibitors, L Lectins

<table>
<thead>
<tr>
<th>Crop</th>
<th>Protein %</th>
<th>Oil %</th>
<th>Carbohydrate %</th>
<th>Fiber %</th>
<th>Anti-nutritionals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phaseolus spp (n=6)</td>
<td>21.4 (1.5)</td>
<td>1.2 (0.4)</td>
<td>57.8 (13.8)</td>
<td>13.9 (7.7)</td>
<td>PA, T, S, TI, L</td>
</tr>
<tr>
<td>Vigna spp (n=8)</td>
<td>22.1 (2.5)</td>
<td>1.9 (1.8)</td>
<td>61.6 (3.2)</td>
<td>11.1 (5.5)</td>
<td>PA, T, S, TI</td>
</tr>
<tr>
<td>Vicia spp (n=2)</td>
<td>24.5 (2.2)</td>
<td>1.3 (0.3)</td>
<td>57.5 (1.1)</td>
<td>14.8 (14.4)</td>
<td>T</td>
</tr>
<tr>
<td>Pisum spp (n=2)</td>
<td>15.4 (11.9)</td>
<td>1.3 (0.2)</td>
<td>37.5 (37.0)</td>
<td>14.8 (14.3)</td>
<td>PA, T, TI, CI, L</td>
</tr>
<tr>
<td>Soybean</td>
<td>36.5</td>
<td>19.9</td>
<td>30.2</td>
<td>9.3</td>
<td>PA, S, TI</td>
</tr>
</tbody>
</table>

The edible part of these crops can be more adapted for diets needing higher or lower caloric and nutrient contents, depending on the oil/fiber and carbohydrates contents (Table 1). The presence of anti-nutritionals has to be considered, especially in legumes.

Conclusions

In our review, we focused on 49 crops providing proteins for food. Issues for research on these crops concern cropping system design, breeding for yield increase, yield stability and to diminish the expression of anti-nutritional taking into account the gene-environment interaction.

References

DIFFERENCES IN NITROUS OXIDE EMISSIONS AMONG FABA BEAN (*Vicia faba*) CULTIVARS IN A BOREAL CLIMATE

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Introduction
An important component of the environmental impact of agriculture is attributed to the production of emissions of nitrous oxide (N\textsubscript{2}O) that account for about 60% of its total greenhouse gas emissions (Cardenas *et al*., 2013). N\textsubscript{2}O emissions have a global warming potential (GWP) over 200 times that of CO\textsubscript{2} emissions (IPCC, 2014), so it is vital to find ways of reducing them.

Nitrogen-fixing legumes can be used to improve the sustainability of cereal-based cropping systems, since they allow a considerable reduction in synthetic fertilizer use and thus can reduce N\textsubscript{2}O emissions from soil, the levels of which can vary depending on the legume species (Schwenke *et al*., 2015). In this study, we evaluated whether N\textsubscript{2}O emissions from faba bean also vary among cultivars. We compared the emissions from 4 faba bean cultivars and barley in a northern European cropping system.

Materials and Methods
A randomized complete block design with four replicates was established in 2015 at the Viikki Experimental Research Farm, University of Helsinki (60°N, 25°E). Faba bean (*Vicia faba* L.) cultivars ‘Kontu’, ‘Fatima’, ‘SSNS-1’ and ‘Alexia’, and barley (*Hordeum vulgare* L.) cv. ‘Harbinger’ were included in the trial. The experiment will continue in 2016 with barley sown to all plots, to test pre-crop effects on N\textsubscript{2}O emissions. The gas fluxes were measured with closed chambers (Epie *et al*., 2015). On each measurement, the gas samples for N\textsubscript{2}O analysis were taken at three times per plot (0’, 20’ and 40’ after closing the chamber) every other week, giving 10 sampling dates during the growing season. The samples were analysed by gas chromatography using an Agilent 7890B Series Custom GC GHG-Analyser equipped with flame ionization, thermal conductivity and electron capture detectors (Agilent Technologies, USA).

Results and Discussion
For the first 3 sampling dates, there were significant differences in N\textsubscript{2}O emissions between sampling dates (*P*<0.001) but not between cultivars (*P*>0.05). The differences between cultivars became more evident as sampling weeks progressed, and cv. ‘Alexia’ emitted less N\textsubscript{2}O than the other cultivars (Figure 1). Data analysis is still in progress.

![Figure 1](image-url). N\textsubscript{2}O emissions from four faba bean and one barley cultivars grown in Finland during 2015. Graph shows data from the first 3 weeks of sampling.
Conclusions
Differences in N$_2$O emissions among faba bean cultivars varied across sampling dates, but were found particularly in the later sampling weeks. Cultivar choice is an important factor for reducing N$_2$O emissions from cropping systems.

Acknowledgements
The FACCE ERA-Net+ project, "Climate Change Adaptability of Cropping and Farming systems for Europe, Climate CAFE" and the Ministry of Agriculture of Finland are acknowledged for funding.

References


**NITROGEN AND GLYPHOSATE APPLICATIONS AFFECT SOIL MICROBIOTA AND PHYSIOLOGICAL PARAMETERS OF COMMON BEAN**


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**Introduction**

Nitrogen (N) and herbicide applications are commonly used to fertilize crops and protect them against weed development, but are also considered as soil and environment pollution sources. In soils, N fertilization is known to induce shifts in microbial community structure and its functional activities (Diosma et al., 2006). Moreover, N fertilization may decrease colonization of roots by arbuscular mycorrhizal fungi (AMF) (Corkidi et al., 2000), a key process in plant nutrition and agrosystem functioning. Among herbicides, glyphosate is the most used in the world, but its effects on non-target soil organisms remain unclear (Druille et al., 2013). The present study aims to assess the individual and combined effects of N fertilization and glyphosate application on soil nutrient status, functional activities, AMF colonization, crop growth and aphid performance on common bean.

**Materials and Methods**

The incubation experiment was set up in November 2015 using soil collected in the field. After sieving, 1600 g of soil were incubated at 25°C at 80% of its water-holding capacity. Glyphosate herbicide was added at 0.96 g active ingredient kg⁻¹ of soil (field rate (FR)) just after incubation. N fertilization was added at 112.5 mg kg⁻¹ of soil two weeks later, just before sowing of bean (*Phaseolus vulgaris* L., non-inoculated with rhizobium). The treatments were as follows: (1) N0\CTRL, untreated soil; (2) N0\FR, soil without N fertilization, treated with Glyphosate; (3) N+\CTRL, soil treated with N, without Glyphosate; (4) N+\FR, soil treated with both N and glyphosate. After three months, soils and plants were sampled. Soil dehydrogenase (DH) and alkaline phosphatase (AlP) activities, catabolic profiles of microbial communities as well as plant physiological (sugars, ammonium, amino acids, chlorophyll, biomass) and biological parameters (mycorrhizal colonization and aphid performance) were measured. Root staining and mycorrhizal infection determination were performed on 1-cm sub-samples of roots. Survival rate and weight of aphid (*Aphis fabae*) nymphs were measured in a 7-day clip cage experiment. Six clip cages were placed per plant, each one containing seven nymphs (< 24 h old).

**Results and Discussion**

Glyphosate and nitrogen application affected enzyme activities and microbial communities. In accordance with Fuentes-Ponce et al. (2016), DH activity was sensitive to N fertilization. Indeed, the addition of inorganic N without glyphosate (N+\CTRL) significantly decreased DH as compared with N0\CTRL whilst in soil with

![Figure 1](image-url). Effect of glyphosate application and nitrogen fertilization on soil enzyme activities, mycorrhizal colonization and pod biomass of common bean. Letters indicate differences among treatments (Dunn’s *post-hoc* test following a significant Kruskal-Wallis test at *P*<0.05).
glyphosate (FR), N+ significantly decreased AlP and AMF colonization. As previously found by Zabaloy et al. (2008), glyphosate at field rate had less effect on microbial parameters than mineral N. On the other hand, without N fertilization and with glyphosate (N0/FR), pod biomass decreased significantly. As microbial activities and AMF are known to improve soil nutrient availability and plant nutrient uptake, non-metric multidimensional scaling revealed correlations between soil microbial indicators (degradation of amino acids, microbial functional activity/diversity, AlP and DH) and plant/aphid responses. It also showed that soils under N0, which were characterized by higher AlP and DH activities, improved plant glucose, fructose and ammonium contents, as well as photosynthesis activity and aphid nymph weight.

References


MULTI-PURPOSE LEGUMES WITHIN SMALLHOLDER FARMING SYSTEMS IN EAST AFRICA: LEGUME CHOICE TOOL

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Introduction
Food insecurity in East Africa is of great concern and much research has focused on improving the food output per unit area through integrated crop-livestock systems in the smallholder farming sector (Fuss et al., 2015; Tscharntke et al., 2012). The East African countries have high population density that has often resulted in high pressure on land, which constrains food and feed production for humans and livestock. Multipurpose legumes are promising interventions within smallholder farming systems where they address problems of food and feed scarcity, poor soil fertility, shortage of income and soil erosion (McIvor et al., 2014, Ojiem et al., 2014). To facilitate improved contribution of multipurpose legumes in smallholder farming, a decision support framework called Legume CHOICE is currently being developed. With the Legume CHOICE tool, decision making towards appropriate legumes that may address different problems in smallholder farming will be supported. Thus this work focuses on gathering data through literature review and research experiments to access the contribution of different types of legumes to food and feed provision, soil fertility improvement, soil erosion control and income generation in smallholder farming.

Materials and Methods
The research is ongoing in two east African countries; Ethiopia and Kenya, in sites where legumes have potential to improve livelihoods. The Legume CHOICE tool comprises three components:
1. A community needs assessment through a baseline survey focusing on general livelihood issues and legumes in smallholder systems at the implementation sites.
2. Scoring the contribution of different legumes to various legume functions.
3. Combining the community needs and legume function expert scoring to generate a prioritized list of options.

Results and Discussion

Table 1. Example of expert scoring for various legumes at implementation sites in East Africa

<table>
<thead>
<tr>
<th>Legume Name</th>
<th>Type</th>
<th>Food</th>
<th>Feed</th>
<th>Income</th>
<th>Erosion Control</th>
<th>Fuel</th>
<th>Soil Fertility</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Phaseolus Vulgaris</td>
<td>Grain Legume, Annual</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>*Cajanus Cajan</td>
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<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
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<tr>
<td>*Mucuna Pruriens</td>
<td>Herbaceous Legume, Annual</td>
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<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>*Desmodium Uncinatum</td>
<td>Herbaceous Legume, Perennial</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>*Calliandra Calothyrsus</td>
<td>Tree Legume Coppicing</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>*Sesbania Sesban</td>
<td>Tree Legume Non-Coppicing</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
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</table>

Kenya: Kisii And Migori

<table>
<thead>
<tr>
<th>Legume Name</th>
<th>Type</th>
<th>Food</th>
<th>Feed</th>
<th>Income</th>
<th>Erosion Control</th>
<th>Fuel</th>
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<td>*Desmodium Uncinatum</td>
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<td>3</td>
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</tr>
</tbody>
</table>

Ethiopia: Diga And Jeldu

*Scale 0 to 4, where 0 indicates no contribution and 4 shows highest function

Based on literature search and expert scoring, multipurpose legumes contribute to provision of income, food, feed and fuel, soil erosion control and soil fertility improvement e.g. (Giller & Cadisch, 1995; Rao & Mathuva, 2000) (Table 1). All these functions were incorporated into the Legume CHOICE tool, as they address some of the problems faced by smallholder farmers. Farmers’ preferences for different legume functions vary, depending on farmer circumstances (Figure 1). Thus the Legume CHOICE tool facilitates in making recommendations on which legumes to use e.g. in study sites in Kenya and Ethiopia income generation and provision food are the...
most critical functions identified, Phaseolus vulgaris and Cajanus cajan can be recommended (Table 1). Contributions of multipurpose legumes to smallholder farmers’ livelihood are varied. Some multipurpose legumes have strong biological nitrogen fixation characteristics and high ground cover that facilitate soil fertility build up and reduced soil erosion. Such characteristics increase grain and stover yield obtained which in-turn can be used to generate income and provide feed for livestock (Fujita et al., 1992; van Kessel & Hartley, 2000). These multipurpose legumes have potential to meet the farmers preferences as far as legume contribution is concerned (Figure 1).

![Figure 1. Pairwise ranking on farmers preferences towards different legume functions in Kenya and Ethiopia.](image)

**Conclusions**

Multipurpose legumes have a niche within smallholder farming sector in east Africa and the Legume CHOICE tool is useful in promoting legume uptake. Farmers’ preferences on legume use vary from place to place and the Legume CHOICE tool offers a range of legume species options that may be used in various farmer situations. Further work is needed on the agro-ecological requirements for various legume species to ensure that the recommendations from the tool will be appropriate to growing conditions.

**References**


