Introducing Legumes into a Portuguese Dairy Forage System: Ecosystem Services and Practical Constraints

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Introduction:

The EU depends on a limited number of cereal crops and imported soymeal to meet its feed requirements. Locally produced roughage contributes only 21% to the EU feed protein supply, while home-grown pulses contribute just 2%. **There is a need to diversify forage systems and an opportunity to do so with legume-cereal intercrops which are minimally adopted in Europe. Showcasing legume Ecosystem Service (ES) provision can be used as a tool to facilitate adoption, while including farmers in the pilot study research is important for maximising the potential for long-term adoption and subsequent service provision.**

Objective:

Investigate ES provision and adoption potential of different legume mixes against the conventionally used cereal/grass mix on a commercial Northern Portugal dairy farm. How can legumes be introduced into a yield optimised context and what benefits do they provide.

Potential Ecosystem Services

Soil quality | **Yield** | **Silage quality**

Assessment through the RE-AIM framework

A framework for judging whether an intervention fits the context and can last (cf. Glasgow et al., 2019, Payne et al., 2019)

REACH

One Dairy farm: stakeholder context and challenges:

- **Vale de Leandro family run dairy farm:** 495 cows and approximately 40 bulls each consuming 50-53 kg of feed per day
- **Feed:** Grass (triticale & ryegrass) and maize silage grown on 60 ha of dispersed plots (1-3 ha each). Soy purchased to increase feed protein content
- **Challenges:** Wild radish infestation managed through herbicides | Acidic soils | Fertiliser dependence (140 kg.ha^{-1} of 40%N fertilizer) | Imported soy dependence for protein | Increasing seed prices

Pilot study design (proposed intervention): split plots of

- **Reference plot:** mixed field of triticale and ryegrass planted at a density of 60 kg.ha^{-1} (30% Triticale, 50% ryegrass)
- **Monoculture control trial plots:** broadcasted and then turned into the soil before cylinder compression
  1. Triticale: 226 kg.ha^{-1}
  2. Faba: 298 kg.ha^{-1}
  3. White Lupin: 267 kg.ha^{-1}
- **Mixed legume plot:** mixed field of triticale, faba, and white lupin (63, 152, and 152 kg.ha^{-1} respectively i.e. 1764 706, 202 723, and 358 490 seeds.ha^{-1})

Motivations

- Triticale intercropping necessary for ensiling
- High nitrogen fixing capacity
- Familiar to Portugal (primarily food)
- Legumes with comparable nutritional profile to soybean and existing proof-of-concept as whole-crop forage for silage

Effectiveness

Performance and ES provision:

Soil quality

- The Reference plot showcased the smallest shift from baseline conditions, suggesting a more minimal influence on soil quality compared to the trial plots
- The high-density intercropped region formed a unique cluster indicating the potential to drive soil health indicators through successful legume/cereal intercropping
- The faba bean showcased little nodulation, and poor performance could be due to sensitivity to the acidic soil

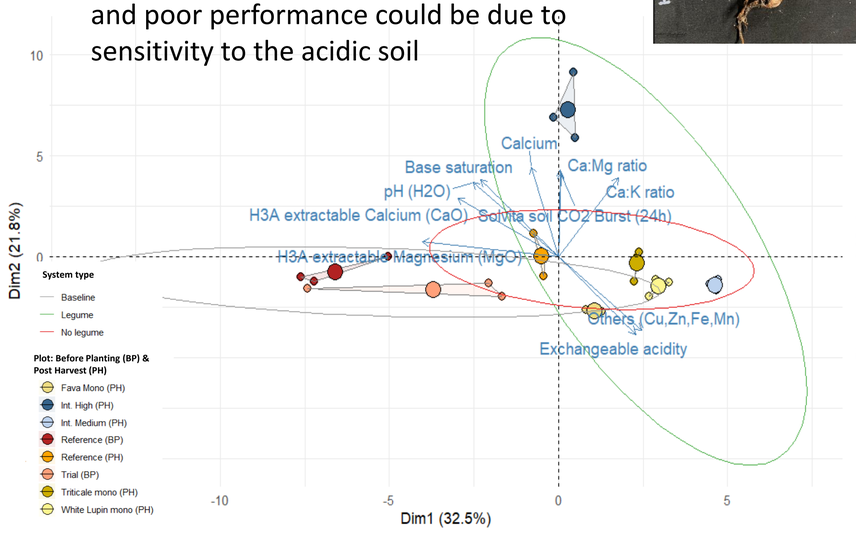

Fig. 1 PCA Biplot illustrating the variance in soil quality between the Vale de Leandro pilot study plots before planting (BP) and post harvest (PH). Showcasing top 10 drivers of variance based on Haney soil analysis.

Yield and weed suppression

- Significantly higher yield for the high-density intercrop and monocultured white lupin
- Faba failed to develop with no presence in the medium density intercropped region

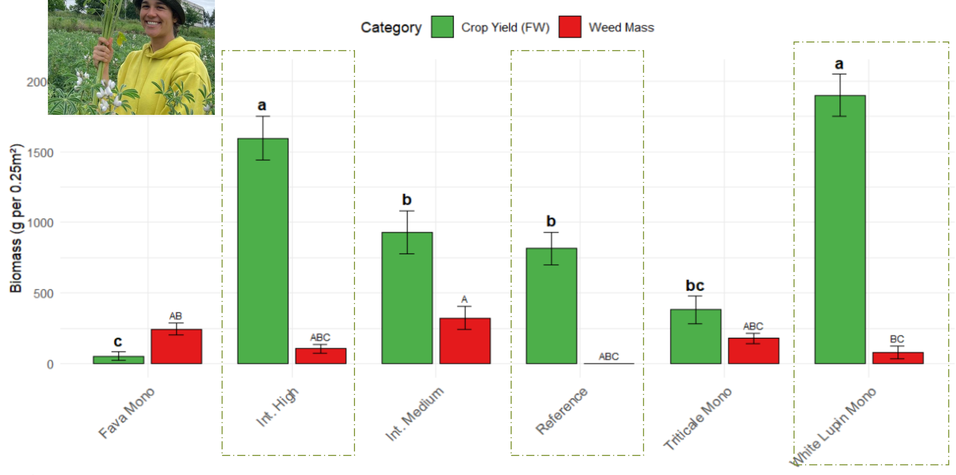

Fig. 2 Target crop biomass and weed infestation per plot (average fresh weight of four sample 0.25 m^2 quadrats)

Silage nutritional quality

- Significant distinction in silage quality with the legume silage strongly associated with increased crude and available protein as well as TTDNFD (total tract neutral detergent fiber digestibility)
- However, silage showed high mold growth due to moisture trapped in un-chopped stems

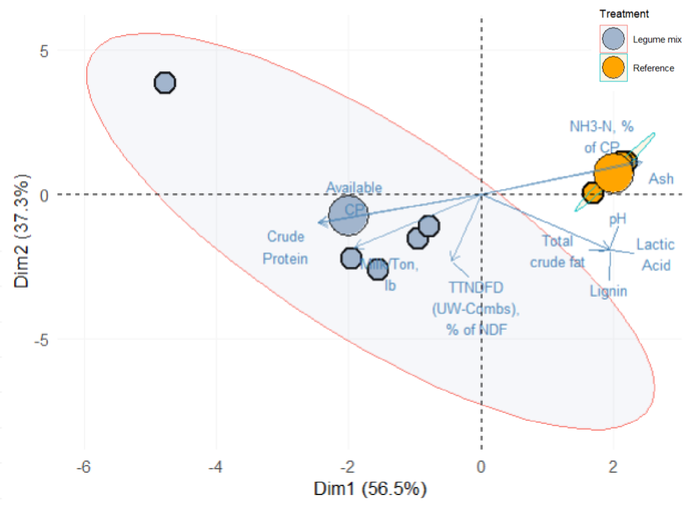

Fig. 3 PCA Biplot illustrating the variance in silage quality between the Reference silage and interval for each silage group, marking the statistically intercropped legume silage g (BP) and post harvest (PH). Showcasing biological drivers of variance with ellipses show the 95% confidence expected center for each system.

Adoption

Participatory farmer response

- **Legume forage and silage not usable:** While the yield was high, white lupin fermented poorly and the stems were too tough for the cows to eat
- **Not compatible with existing machinery:** the white lupin, faba, and triticale seeds cannot be drilled (conventional system) due to differing seed size

Implementation

Trial management and constraints

- **Plant cutting prior to baling was not possible due to small area→** high internal stem moisture and poor fermentation
- **No inoculant added to the silage →** poor fermentation
- **Broadcast seeding →** uneven planting density

Maintenance

Would the farmer grow the intercrop again independently?

- **Not at this stage:** there is potential if a larger area is used to facilitate cutting, but there is still scepticism about planting and ensiling

Conclusions & future prospect

- **Success & ES Provision:** White lupin intercropped at high density provided positive Ecosystem Services (ES) without fertilisers or herbicides.
- **Operational Barriers**: Despite agronomic success, machinery and processing constraints deterred the farmer from future independent adoption.
- **Adaptive Design:** The trial now evaluates two commercial forage legume mixes, incorporating local agronomist expertise to ensure farmer-centric design.
- **Multidisciplinary Necessity: Long-term ES provision requires integrated muti-stakeholder assessment to align scientific goals with 'real-world' operational feasibility.**

Acknowledgments

This research was supported by legumES a Research and Innovation Action funded by the European Commission under Grant Agreement Number 101135512. legumES is also supported by Innovate UK through the Horizon Europe Guarantee scheme and by the Swiss State Secretariat for Education, Research and Innovation (SERI), Grant N° 23.00034 and 23.00645