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SYSTEMS AGRONOMY FOR RE-DESIGNING ORGANIC GRAIN LEGUME CROPPING SYSTEMS

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Abstract: The integration of grain legumes into European agricultural systems could contribute to the transition to more sustainable food production. While the general benefits from legume cultivation are widely known, especially in organic farming, there is little evidence on how to re-design organic cropping systems with legumes to make this option more attractive to farmers. The objectives of this study were to describe the constraints and opportunities of organic grain legume production perceived by farmers, explain the agronomic impacts of current grain legume cropping, explore technical options to improve grain legume agronomy, and to re-design current grain legume cropping systems in a participatory process with farmers. A co-design approach was implemented with organic farmers, advisors and scientists on 25 farms in northern Germany, that were part of two large demonstration networks of about 100 farms supporting grain legumes across Germany. We used the DEED research cycle (Describe, Explain, Explore and Design) as a conceptual framework combining on-farm research, crop rotation modelling, and on-station experiments. From it, we identified nine agronomic practices that either were novel or confirmed known strategies under new conditions, to re-design organic grain legume cropping systems at the field and farm level. We also demonstrate how to complement knowledge of farmers' perceptions (Describe step) and formal knowledge from classical on-station experiments and modelling (Explain step) with on-farm research including the local views of farmers (Explore step) to identify tailored options for specific farm contexts rather than prescriptive solutions (Design step) to intensify legume production. This approach therefore contrasts with traditional methods that are often solely participatory and qualitative or model/experimental-based and quantitative. Hence, our results provide new insights in how to re-design cropping systems using a combination of participatory and quantitative approaches. While participatory approaches are common in developing countries, this study shows their potential in an industrialized context with large-scale farmers in Europe. These novel findings can be used as a starting point for further adaptations of organic cropping systems and contribute to the transitioning towards economically and environmentally more sustainable food and feed systems.

Introduction: The integration of grain legume crops into European agricultural systems could contribute to the transition to greater sustainability in agricultural production and reduce some of the negative impacts (Voisin et al., 2014). While the general agronomic, environmental and economic benefits from legume cultivation have been reviewed extensively (e.g. Watson et al. 2017), there is little evidence on how to re-design organic cropping systems with legumes to make this option more attractive to farmers.

The aim of this study is to introduce a novel approach for the re-design of organic cropping systems with a focus on the agronomic implications. The specific objectives were (1) to describe farmers' perceived constraints on, and opportunities for, grain legume production, (2) to explain the agronomic impacts of current grain legume cropping, (3) to explore technical options at the field scale to improve grain legume agronomy, (4) to identify practices for re-designing current grain legume cropping systems, (5) to evaluate the role of different methods in agronomy and (6) to evaluate the contribution of the DEED research cycle for the re-design of grain legume cropping systems in a participatory research project. Northern Germany was selected as a case study area because we have already found significant trade-offs between economic and environmental impacts for integrating grain legumes into cropping systems in parts of this region (Reckling et al., 2016).

Material and methods: The present study builds on an active researcher-farmer cooperation in two large demonstration networks supported through the German protein crop strategy with a focus on narrow-leafed lupin (*Lupinus angustifolius* L.) (NL lupin) as an established crop and soybean (*Glycine max* (L.) Merr.) as a potential novel crop in the area. On-farm trials, on-station experiments and crop rotation modelling of farming systems across northern Germany were used in this study. More details of the study design and process is provided by Reckling et al. (2020).

Results: In the co-learning process, we contributed to the re-design of farmers' cropping systems through the identification of nine practices that were tailored to specific farming contexts and were already influencing the implementation by farmers during the research project. The practices either were novel, confirmed known strategies under new conditions or provided additional evidence for implementing certain activities. While some practices were tested only during single years, e.g., nutrient fertilizers, others were tested over up to four years, e.g., soybean as an alternative grain legume. Hence results can be interpreted as farm-specific innovations. The practices included (i) inter-row hoeing , (ii) direct seeding into a cover-crop, (iii) species-specific inoculation, (iv) cover crops to reduce leaching, (v) reduced tillage, (vi) soybean for increased gross margins, (vii) cultivars for food and feed use, (viii) flexible irrigation, (ix) grain legumes with cover crop to enhance subsequent crop yields. We also demonstrate how to complement knowledge of farmers' perceptions (Describe step) and formal knowledge from classical on-station experiments and modelling (Explain step) with on-farm research including the local views of farmers (Explore step) to identify tailored options for specific farm contexts rather than prescriptive solutions (Design step) to intensify legume production.

The co-design process following the DEED cycle provided new insights into the use of different methods for the re-design of cropping systems with legumes. These insights include the need to complement knowledge on farmers' perceptions (Describe step) with formal knowledge from classical on-station experiments and modelling (Explain step) and on-farm research (Explore step) to identify tailored options for specific farm contexts rather than prescriptive solutions (Design step) to intensify legume production. The approach is different from traditional approaches that are often solely participatory and qualitative (bottom-up) or model/experimental-based and quantitative (top-down).

Discussion: We conclude that working in a participatory research process with large-scale organic farmers in Europe in a co-learning process provided new insights into using systems agronomy to re-design legume-supported cropping systems. Our study highlights the need of complementing formal knowledge from classical on-station experiments and

modelling with on-farm research including the local views of farmers. We adapted a conceptual framework to facilitate the co-learning between farmers, advisors and scientists to re-design cropping systems using different methods of agronomy and identified potential challenges. Through this framework, we identified a set of nine agronomic practices that are a starting point for further adaptations to suit specific farmers' needs. The practices increase the benefits of the most important services of grain legumes, provisioning of protein, nitrogen fixation and rotational effects, and reduce potential constraints with weeds and nitrate leaching. Implementing these practices contributes to making grain legumes economically and environmentally more attractive, supporting the transitioning towards sustainable food and feed systems. Options to reduce nitrate leaching after soybean, identify adapted soybean cultivars for the growing food market and implement a second co-learning cycle to follow up on farmers' strategies warrant further investigation.

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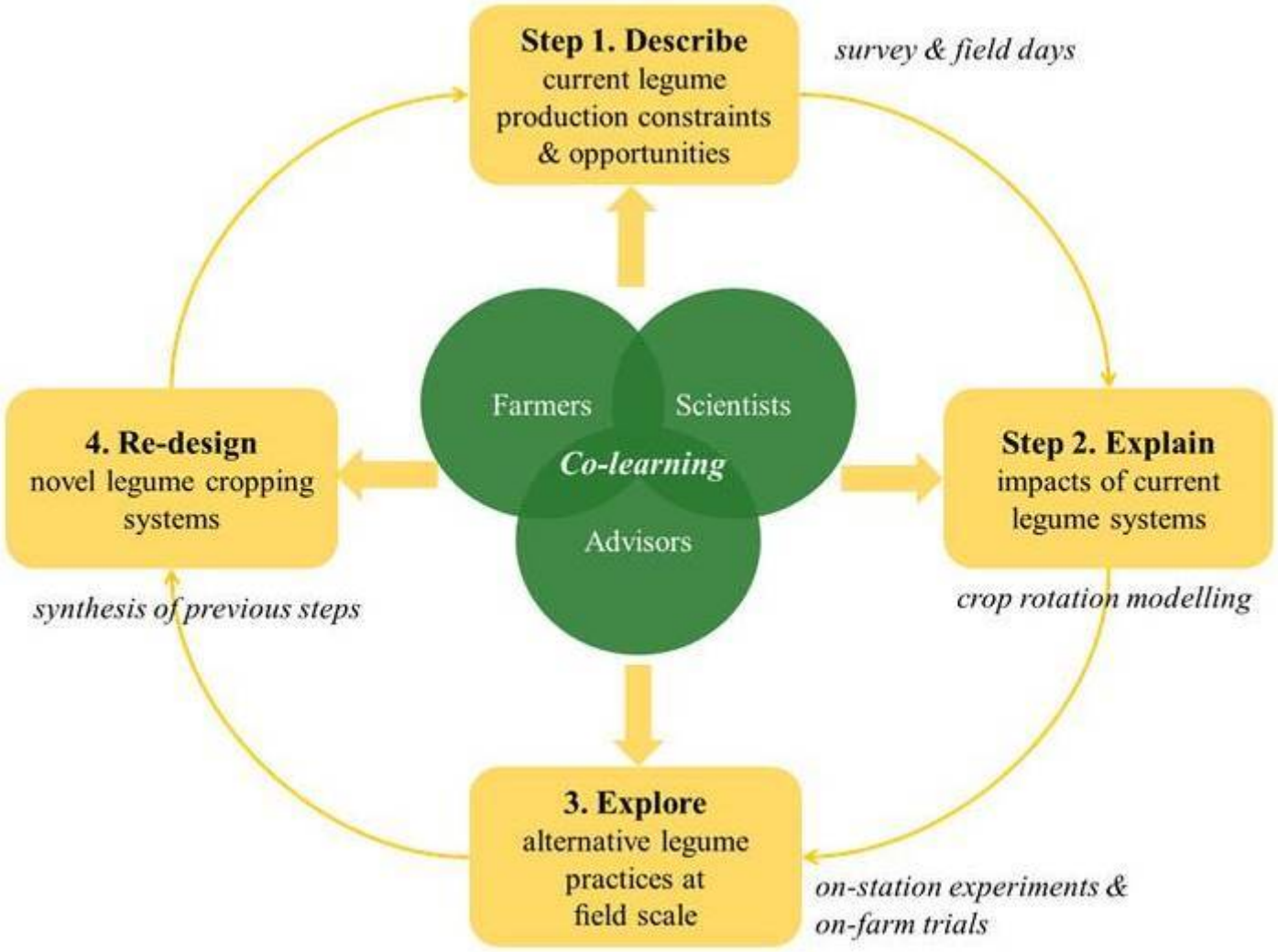
Image:



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