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VALPRO path.

NEW VALUE LANDSCAPES FOR PLANT PROTEIN PATHWAYS

D4.1. Report on Cost and Benefit Assessment

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Executive Summary

Increasing the production of protein crops for food is an important goal of European agricultural policy. Despite their agronomic benefits, the cultivation of protein crops remains limited. Within the VALPRO Path project, this assessment evaluates the on-farm competitiveness of chickpea, lupin, pea, and faba bean across four representative production systems in different European countries. The assessment is based on representative farm-level data from 2022–2024 and includes gross margin analyses, parity price calculations, and sensitivity analyses, complemented by focus group discussions addressing agronomic and market-related factors affecting economic viability.

The economic performance of protein crops is assessed using extended gross margin calculations that compare each protein crop with the most relevant alternative crop(s) within the respective crop rotation. At the crop-rotation level, the baseline rotation is compared with an alternative rotation that incorporates the respective protein crop. The extended gross margin approach incorporates monetized crop rotation effects, including yield increases in subsequent crops as well as savings in fertilizer and crop protection expenditures. The results demonstrate that the competitiveness of protein crops depends strongly on local agronomic, market, and policy conditions. Among the assessed crops, faba beans in Ireland achieve the strongest economic performance, whereas the competitiveness of lupins, peas, and chickpeas is more limited under the evaluated conditions.

Based on the findings, the following conclusions can be drawn:

1. Access to human food markets represents the most important opportunity to improve the competitiveness of protein crops and reduce their dependence on governmental support payments. However, European protein crops compete with imported products. Consequently, a better understanding of these markets is essential for achieving sustained long-term improvements in marketing opportunities and market access.

2. Crop protection remains a major challenge in protein crop production. Avoiding further reductions in the availability of crop protection products, and where possible expanding the range of available options, would substantially support the expansion of domestic protein crop cultivation.

3. Increasing weed management challenges in winter crop-dominated rotations may create new opportunities for protein crop cultivation. The inclusion of protein crops can diversify weed management strategies and contribute to the control of problematic weed species, particularly grass weeds.

4. The identification, quantification, and monetization of crop rotation effects should become a priority for both research and advisory services. In addition to the weed management benefits described above, the assessment identified substantial crop rotation effects across several case studies. Improving the understanding and communication of these benefits could support more informed farm-level decision-making and enhance the adoption of protein crops.

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Table 1: List of abbreviations and acronyms

List of Abbreviations and Acronyms	
CAP	Common Agricultural Policy
non-GMO	non-Genetically Modified Organisms
IPS	Innovative Production System
VPP	VALPRO Path

1. Introduction

The VALPRO Path (VPP) project addresses key challenges in European plant-based protein production by advancing sustainable, innovative, and economically viable value-chain solutions. The project aims to guide stakeholders across the entire value chain, from on-farm production to processing and market integration, toward more resilient systems for producing plant-based proteins for food and feed. By focusing on the development, validation, and demonstration of novel approaches, VPP seeks to contribute to closing the European protein production gap while supporting the transition toward sustainable agri-food systems.

Central to the project are Innovative Production Systems (IPSs) that prioritize the cultivation of high-value protein crops, including peas, lupins, chickpeas, faba beans, soybeans, and lentils. These IPSs integrate advanced cultivation, processing, and crop rotation strategies to enhance productivity, sustainability, and resource efficiency. For each IPS, VPP develops tailored circular value-chain business models that reflect regional contexts and market conditions.

The project is implemented through five multi-stakeholder IPSs with strong industry involvement, ensuring practical relevance and impact. In addition, VPP applies a multi-criteria mathematical modeling and optimization framework that combines Life Cycle Sustainability Assessment, advanced data acquisition, and sustainable crop planning tools. Through a collaborative, multi-actor approach, VPP aims to co-create added value for European legume crops, stimulate growth in the plant protein sector, and contribute to economic vitality and societal well-being in alignment with the objectives of the European Green Deal.

To achieve these aims, *Task T4.4. Cost and Benefit Assessment for demonstrated crops of selected IPSs*, is designed to provide a robust evaluation of the on-farm competitiveness of protein crops across different European countries. The task investigates the conditions under which farmers can profitably integrate protein crops into their existing cropping systems, with a particular focus on their use for human consumption. To this end, key economic parameters, including yields, output prices, and production costs, are quantified for protein crops and their competing crops within the crop rotation using a representative farm approach.

A baseline rotation without protein crops is compared with an extended crop rotation that includes a protein crop. Building on this comparison, further analyses examine the crop rotation effects of protein crops, parity prices, and the sensitivity of economic outcomes to variations in yields and prices. In addition to quantitative economic indicators, focus group discussions with farmers and agricultural advisors are conducted to systematically identify and assess qualitative factors influencing the economic viability of protein crop cultivation, such as crop rotation effects, yield variability, and associated risks.

The assessment covers the following crop-country combinations: chickpea in Apulia (Italy), lupin in Western Pomerania (Germany), pea in Funen (Denmark), and faba bean in Leinster (Ireland). The analysis is based on farm-level data collected for the period 2022–2024.

Against this background, the following research questions are addressed to evaluate the economic competitiveness of protein crops within existing cropping systems:

How competitive are protein crops at the farm level across selected European regions, considering economic and agronomic factors?

a) How do crop rotation effects and cost changes affect protein crop competitiveness?
b) Which agronomic factors influence the viability of protein crop cultivation?
c) How sensitive are farm-level economic outcomes to variations in yields and prices?

2. Methodology

The methodology described below is applied consistently across all crop–country combinations to ensure comparability of results. The assessment follows a structured, stepwise approach combining quantitative farm-level economic analysis with qualitative validation through stakeholder engagement. The selection of the crop-country combinations was defined by the project coordination in consultation with the other project activities, ensuring consistency with the field trials and adequate coverage of the protein crops included in the project.

Selection of Regions and Crop Rotations

The first step involves identifying the crop acreage of the selected protein crops within each country using official national and international statistical databases. Based on these statistics, a representative region in the country is selected that combines a comparatively large share of the national cultivation area with a high regional concentration of the assessed crop. This ensures that the selected region represents an important production area for the respective protein crop.

In collaboration with local partners from advisory services, a typical crop rotation is defined to represent the baseline rotation for each selected region. A crop rotation refers to the sequence of crops cultivated on the same field over multiple years. The selected baseline rotation reflects regionally prevalent cropping systems, however, the protein crop under assessment is explicitly excluded.

To assess the introduction of protein crops, an extended crop rotation is developed together with local partners by integrating the protein crop into the baseline rotation. Depending on the regional context, the protein crop either extends the crop sequence, resulting in a longer rotation, or replaces an existing crop within the rotation. The positioning of the protein crop within the rotation is determined by crop rotation interactions, particularly the effects of preceding crops and the impacts on subsequent crops. The total cultivated area remains identical between the baseline and protein crop rotation, ensuring that land use differences do not affect the comparison.

Calculation of Gross Margins

Farm-level data are collected for the protein crop and all other crops included in the assessed rotations. The data aim to be representative of the selected regions and cover the assessment period from 2022 to 2024. Data are compiled from advisory services, statistical sources, and expert judgment, and are cross-checked for plausibility. All yields are measured in tonnes per hectare, output prices in euros per tonne, and all cost and revenue components in euros per hectare.

Revenue-related data comprise yields and output prices as the primary determinants of crop revenues. Where applicable, additional revenues from by-products are included. Governmental support payments are also taken into account, encompassing all payments directly associated with the cultivation of the respective crop.

The crop rotation effects of the protein crop are calculated by monetizing documented yield benefits and nitrogen savings in subsequent crops using output prices and mineral fertilizer nitrogen prices. If applicable, additional savings in pesticide expenditures are also included in the calculation of the crop rotation effect.

The choice of an appropriate economic performance indicator depends on whether or not the introduction of a protein crop leads to changes in fixed costs at the farm level. Based on the focus group discussions, it is assumed that the integration of protein crops does not require additional machinery or result in substantial changes in labor requirements. Furthermore, it is assumed that there is no post-harvest processing on-farm and hence no respective additional investments are required. Reasons for using existing farm machinery are: Sowing is carried out with standard cereal seed drills, while harvesting is performed with standard combine harvesters. In cases where additional equipment is needed (e.g. harrows or hoes), it is assumed to be available on-farm or through contractors. Second, labor requirements are not expected to increase. Protein crops typically require fewer fertilizer and plant protection applications than many competing crops. Under these assumptions, the introduction of protein crops only affects revenues and direct production costs, while fixed costs remain unchanged. Therefore, gross margins are considered an appropriate indicator for assessing the economic effects of integrating protein crops into existing crop rotations, as they capture the relevant differences between the baseline and protein crop rotations. Since the objective of the assessment is to evaluate the relative economic effects of integrating protein crops into existing crop rotations, differences in gross margins – either per crop or per rotation – are the relevant performance indicator.

Gross margins are calculated by subtracting direct costs from total revenues. Direct costs comprise expenditures for seeds, fertilizers, pesticides, and miscellaneous costs. Variable cost components that are not affected by changes in the cropping system, such as insurance, seasonal labor, contractor services, fuel, machinery repair and maintenance, are excluded from the analysis. To calculate gross margins at the crop rotation level, each crop's share of the total cultivated area within the rotation is expressed as a percentage. A weighted average margin is then calculated based on the crop-specific gross margins and their respective acreage shares. All calculations are performed both including and excluding all governmental support payments to illustrate their influence on economic outcomes. Results are calculated for each individual year and reported as three-year averages and ranges (see Table A-1–Table A-4 in the Appendix).

Qualitative Validation through Focus Group Discussions

The calculated gross margins are validated through focus group discussions involving farmers, an agricultural advisor and scientists. The focus group discussions are jointly organized by the project lead and the respective local partner. For the Danish and Irish case study, an expert interview with an agricultural advisor was conducted instead of a focus group discussion due to the limited availability of suitable participants. The objective of these discussions is to systematically identify and assess additional agronomic and economic considerations relevant to the viability of protein crops. Each focus group consists of three to five farmers, one advisor, and one or two scientists and is conducted as an in-person meeting. Participants are not required to be current protein crop growers, although a demonstrated interest in the topic is expected. Key guiding questions, developed by the project lead and shared with local partners, provide the framework for the discussion and are shared with participants prior to the meeting. Following the focus group discussion, a detailed written protocol is prepared and shared with all participants. The protocols, including the key guiding questions, are provided in the Appendix (Protocol A-1–Protocol A-3). No protocol is available for the Irish expert

discussion. The first part of the discussion addresses agronomic aspects of protein crop cultivation, including soil and climate requirements, crop rotation design and crop rotation effects, tillage, sowing, fertilization, plant protection, harvesting, and marketing. The second part focuses on validating and discussing the calculated gross margins for both crop rotations. All information about agronomic and economic challenges provided in the subsequent chapters has been derived from said protocols unless specified otherwise.

Advanced Economic Analyses

Based on the validation of economic and agronomic information and data, additional economic analyses are conducted to assess the competitiveness of protein crops under varying market conditions. This includes the calculation of parity prices, defined as the output price at which the protein crop achieves the same gross margin as the competing crop. The calculations incorporate crop-specific yields, direct production costs and crop rotation effects and are conducted both with and without governmental support payments. Parity prices are calculated at both the crop and crop rotation levels. At the crop level, the analysis evaluates the competitiveness of the individual protein crop relative to the competing crop within the rotation. At the crop rotation level, parity prices are used to determine the price required for the protein crop rotation to achieve the same profitability as the baseline rotation.

To assess the relationship between protein crop and cereal markets, annual price ratios between wheat and the respective protein crops were calculated. Wheat was selected as the reference crop because it is widely grown across all assessed regions and represents an important benchmark crop in European arable systems. The wheat-to-protein crop price ratio provides an indication of the relative market value of protein crops compared to cereals and allows differences in market positioning to be assessed. A relatively stable price ratio over time may indicate a close linkage between wheat and protein crop markets, with prices responding similarly to changes in supply and demand. Conversely, substantial deviations from the typical wheat-to-protein crop price ratio observed for feed protein crops may indicate access to alternative market segments.

Sensitivity analyses are conducted to assess the influence of yield and price variability on the economic performance of protein crops. For the yield sensitivity analysis, annual yield deviations from the three-year average are evaluated while all other parameters remain constant. Similarly, the price sensitivity analysis assesses the impact of annual price variations from the three-year average while holding all other parameters constant. Isolating individual parameters allows the effects of yield and price variability on profitability to be quantified. This approach allows the main sources of economic risk to be identified and provides insights into the robustness of protein crop competitiveness under different production and market conditions. To avoid redundancy, only the sensitivity analysis of the parameter with the larger effect on economic performance, either yield or price, is presented in the report.

3. Results and Discussion

3.1. Cultivation of Protein Crops in Europe

The following chapter presents general agronomic information on protein crop cultivation in Europe to give appropriate context to the results that follow from the analysis. Crop-specific characteristics of the individual protein crops assessed are discussed in the corresponding chapters and summarized in crop profiles provided in the appendix (Profile A-1–Profile A-4). Grain legumes such as chickpea, lupin, pea, and faba bean belong to the family *Leguminosae* and are characterized by their ability to fix atmospheric nitrogen through symbiosis with rhizobia (Palmero et al., 2022). As a result, nitrogen

fertilization is often not required. In addition, grain legumes contribute to crop diversification, interrupt disease, pest, and weed cycles in cereal-dominated rotations, and can improve the performance of subsequent crops. Their relatively deep rooting systems may improve soil structure and nutrient uptake from deeper soil layers. Owing to their high protein content, grain legumes represent valuable crops for both food and feed markets (Preissel et al., 2015; Watson et al., 2017).

Protein crops typically have moderate soil requirements; however, shallow soils and waterlogged conditions should be avoided. While lupins are well adapted to sandy and low-fertility soils, faba beans generally require higher soil quality and water availability (Stoddard & Schauman, 2022). Because protein crops are susceptible to several crop-specific pests and diseases, adequate cultivation breaks of four to six years are required (Watson et al., 2017). Excessive residual soil nitrogen from the preceding crop should be avoided, as it may reduce biological nitrogen fixation. Winter crops such as winter wheat, winter barley, winter oilseed rape, or cover crops are particularly suitable subsequent crops because they can efficiently utilize residual nitrogen (Reckling et al., 2016).

The crop rotation effect describes the influence of a crop on the performance of subsequent crops within the rotation (Preissel et al., 2015). For protein crops, the most important effects include yield increases in following crops, nitrogen fertilizer savings resulting from biological nitrogen fixation, and, in some systems, reductions in plant protection expenditures. Additional benefits may arise from lower weed, pest, and disease pressure, improved soil structure, simplified tillage operations, and a more balanced distribution of labor requirements throughout the year. The magnitude of these effects varies widely depending on site conditions, crop rotation, and management practices (Notz & Reckling, 2022; Preissel et al., 2015). While yield increases, reductions in nitrogen fertilizer requirements, and savings in pesticide expenditures can be easily quantified economically and are therefore incorporated into the analysis as components of the crop rotation effect, the other agronomic effects are more difficult to express in monetary terms.

Despite these benefits, protein crops may also present agronomic challenges. Slow early growth reduces their competitiveness against weeds, making appropriate field selection, tillage practices, and crop establishment particularly important (Rühl et al., 2009). In addition, the range of registered herbicides, fungicides, and insecticides is generally more limited than for major cereal crops. As a result, weed management in particular, but also pest and disease management, are frequently identified as major challenges in protein crop production. Mechanical weed control using harrows or hoes is possible but is not widely adopted in current protein crop production systems (Kousta et al., 2024; Rühl et al., 2009).

Protein crops are generally seeded between February and April using a standard cereal drill. The harvest takes place between August and September with a standard combine harvester (Rühl et al., 2009). Although biological nitrogen fixation substantially reduces nitrogen fertilizer requirements, adequate macro- and micronutrient supply remains necessary depending on soil nutrient status (Rühl et al., 2009). Yield levels vary considerably among protein crops and are often characterized by relatively high year-to-year variability (Preissel et al., 2015). In addition, quality requirements depend on both the crop species and the intended end use. Harvested grains can be used on-farm for livestock feeding or marketed for further processing into animal feed, human consumption, and seed production (Rühl et al., 2009).

3.2. Chickpea Cultivation in Apulia, Italy

3.2.1. Regional Context and Cropping Systems

Chickpea Cultivation in Italy

In Italy, an average area of approximately 14,480 ha was cultivated with chickpeas during the period 2022–2024. After a decline from the peak cultivation area observed in 2018, chickpea cultivation has shown a gradual increase in recent years. The main producing regions were Molise (2,220 ha), Tuscany (2,200 ha), and Apulia (1,920 ha) (Istat, 2026). As regional differences in chickpea production are relatively limited and the local partner has strong regional expertise, Apulia is selected as the representative region for the assessment of chickpea cultivation in Italy.

Regional Conditions in Apulia

Apulia is located in southern Italy and is characterized by a Mediterranean climate with hot, dry summers and mild winters. Mean annual temperature amounts to approximately 16.5 °C, while average annual precipitation is about 550 mm (Copernicus Climate Change Service, 2026), with most rainfall occurring between autumn and early spring. The region is therefore characterized by limited water availability during the growing season. Soils are predominantly calcareous, with low organic matter contents and limited water-holding capacity. These conditions favor drought-tolerant crops such as chickpeas and contribute to the importance of water availability and yield stability for economic performance.

Characteristics of Chickpea Cultivation

Chickpea (*Cicer arietinum* L.) is a grain legume well adapted to Mediterranean and semi-arid environments due to its relatively deep rooting system and good drought tolerance (see Profile A-1). It is suited to well-drained, light soils and can be cultivated under relatively low-input conditions. The dominant chickpea type cultivated in Italy is the Kabuli type, characterized by large, light-colored seeds (De Santis et al., 2021; Sellami et al., 2021). Chickpea seeds contain approximately 19 % protein (Sinkovič et al., 2023) and are primarily used for human consumption, either as whole seeds, flour, or processed food products (Donna et al., 2025).

Crop Rotations in Apulia

Before describing the crop rotations assessed in Apulia, several structural and agronomic characteristics of the regional farming systems need to be considered. Farms in Southern Italy, and particularly in Apulia, are traditionally organized around durum wheat production. Durum wheat is the dominant crop in the region due to its cultural and historical importance and its close link to the Italian pasta industry. Consequently, crop rotations are typically designed around durum wheat, while other crops primarily serve agronomic functions such as maintaining soil fertility, reducing pest and disease pressure, and enhancing diversification. Focus group results suggest that crop choice is driven more by local and cultural farming traditions than by detailed crop-level profitability analyses. As family labor, which constitutes a large share of labor input on predominantly small-scale farms, is rarely valued at opportunity cost, current cropping patterns reflect established farming systems rather than fully profit-optimized production decisions. The extent to which these systems will remain competitive under ongoing structural and economic change, however, remains uncertain.

The baseline rotation considered in this assessment consists of a three-year sequence of durum wheat, durum wheat, and spinach. Each crop accounts for 33 % of the total rotation area. The vegetable spinach requires irrigation and intensive crop management, which limits its cultivation to farms and fields with access to irrigation.

To integrate a protein crop into this rotation, spinach is replaced by chickpeas. The resulting protein crop rotation consists of durum wheat, durum wheat, and chickpeas, with each crop again representing 33 % of the total rotation area. Spinach and chickpeas are generally not included within the same field-level rotation due to phytosanitary constraints associated with the insect noctuid moths (Noctuidae). The larvae of these insects frequently overwinter in the soil and may infest young chickpea crops after emergence. Early infestations can cause significant feeding damage to leaves and stems, to which chickpeas are particularly sensitive during the early growth stages. Consequently, chickpeas are generally not cultivated on fields that form part of the irrigated spinach rotation.

According to the focus group participants, chickpeas are generally cultivated under rainfed conditions, whereas spinach is produced under irrigated conditions. Although supplemental irrigation may improve chickpea yields and yield stability, particularly under drought conditions, it is not commonly applied in chickpea production. Consequently, no empirical data are available to quantify the potential yield benefits of irrigated chickpea production. This distinction should be considered when interpreting the economic results, as the competitiveness of chickpeas may be underestimated under the assumption of exclusively rainfed production.

The choice of the chickpea rotation is based primarily on agronomic considerations rather than purely economic ones. While spinach generally achieves higher profitability on suitable irrigated land, chickpeas provide benefits that can justify their inclusion at whole-farm level, including their nitrogen-fixing capacity, their compatibility with local farming practices, and their role in supporting soil fertility and crop diversification within durum wheat-based systems.

In practice, not all farms in the region grow spinach, and where spinach is cultivated, its share within the cropping system is often considerably lower than assumed in the case study. Consequently, the introduction of chickpeas may replace crops with lower profitability than spinach, such as durum wheat, resulting in a more favorable economic position for chickpeas than indicated by the case study results. Additionally, adoption of protein crops will depend on individual farm circumstances. Rather than fully replacing spinach production, chickpeas are more likely to be introduced on land where irrigation is unavailable, limited, or subject to stricter water-use restrictions. Consequently, an irrigated spinach containing rotation and a rainfed chickpea containing rotation may coexist within the same farm, with land allocation determined by irrigation access, agronomic suitability, and farm management objectives. At whole-farm level, this would likely result in a partial reallocation of land from existing cropping activities towards protein crops rather than a complete substitution of spinach cultivation. The rotation comparison should therefore be interpreted as a comparison of alternative cropping systems rather than a representation of a direct substitution of spinach by chickpeas.

3.2.2. Gross Margin Analysis

Yields and Prices

Chickpea yields during the assessment period vary between 1.5 and 3.3 t/ha, with a three-year average of 2.2 t/ha (see Table A-1 in the Appendix). Taking the average yield of the years 2022–2024 as the reference value (100 %), annual chickpea yields range from 69 % to 146 % of the average yield. In contrast, annual yields of durum wheat and spinach vary only between 91 % and 106 % of their respective average yields. The second durum wheat in the rotation achieves yields approximately 10 % lower than those of the first durum wheat due to consecutive cultivation. Overall, the higher yield variability observed for chickpeas indicates a greater production risk relative to the competing crops.

Price fluctuations are less pronounced than yield fluctuations for chickpea. The average chickpea price amounts to 786 €/t and varies between 747 and 860 €/t (95–109 % of the three-year average). The

comparatively high price level, combined with moderate price variability, reflects the predominant use of chickpeas for human consumption. In contrast, the competing crops exhibit considerably higher price variability, ranging from 83 % to 124 % of their respective average prices. Overall, the results demonstrate that the economic performance of chickpeas is influenced more strongly by yield fluctuations than by price changes. The implications of this finding are further analyzed in the sensitivity analysis (3.2.3).

Revenues and Costs

Chickpea achieves average revenues of 1,805 €/ha (1,190–2,860 €/ha). In addition to revenues from chickpea sales, chickpea producers receive governmental support payments of 40 €/ha for protein crop cultivation under the EU Common Agricultural Policy (CAP) (Ministry of Agriculture, 2026). However, these payments contribute only marginally to total chickpea revenues, accounting for approximately 2 % of total revenue. Although positive crop rotation effects of chickpea cultivation are frequently reported in the literature, they are not considered economically relevant by farmers participating in the focus group discussion. These findings suggest that the economic performance of chickpea production is primarily determined by market revenues and production performance. Spinach generates the highest revenues, averaging 2,525 €/ha, reflecting its status as a high-value irrigated vegetable crop. Its economic advantage is closely linked to irrigation and the high market value of the crop. Chickpea revenues exceed those of durum wheat, which averages between 975 €/ha and 1,072 €/ha during the assessment period. For durum wheat, additional revenues from straw sales (approximately 27 €/ha) and governmental support payments (100 €/ha) (Rete Rurale Nazionale, 2026) are included in the analysis. The support payment is intended to support traditional pasta production in Italy. Consequently, average revenue levels differ considerably among the assessed crops.

Direct costs of chickpea production are intermediate compared to the competing crops. Average direct costs of chickpea cultivation amount to 675 €/ha (647–692 €/ha), which is considerably lower than for spinach (1,102 €/ha), but higher than for the first and second durum wheat (483 €/ha and 553 €/ha, respectively). Seed and pesticide costs represent the largest cost components of chickpea production, accounting for 56 % and 34 % of total direct costs, respectively, while fertilizer costs remain low due to biological nitrogen fixation (9 % of total direct costs). The higher costs of the second durum wheat result from an additional phosphorus application, which provides a residual fertilization effect for the entire crop rotation. Cost variability is also lower for chickpea (96–102 %) than for the competing crops (92–109 %).

Gross Margins at Crop Level

Spinach achieves the highest average gross margin (1,423 €/ha), highlighting its economic importance within the baseline rotation. Although chickpea generates lower revenues than spinach, its moderate production costs result in a gross margin of 1,129 €/ha (543–2,168 €/ha), making it the second most profitable crop in the assessment. Gross margins of durum wheat are substantially lower, reaching 589 €/ha for the first and 423 €/ha for the second durum wheat. Consequently, chickpea represents an economically viable crop option, but faces difficulties matching the profitability of the high-value irrigated crop spinach. Excluding support payments has only a minor impact on the results. The gross margins of chickpeas show exceptionally high variability (48–192 %), substantially exceeding the variability observed for the competing crops. This reflects the strong dependence of chickpea profitability on both yield and market conditions. Spinach shows greater gross margin variability (63–138 %) than both the first (83–115 %) and second durum wheat (81–117 %).

Since the assessment is based on gross margin and direct cost calculations (excluding fuel cost), variable irrigation costs are not accounted for, although spinach is cultivated under irrigated conditions. To evaluate the potential influence of irrigation costs on the economic results, a simplified calculation is conducted. The average gross margin advantage of spinach over chickpeas amounts to 294 €/ha. Data from other *agri benchmark* analyses of Italian crop production indicate that variable energy costs for irrigation are approximately 40 €/ha. Fixed irrigation infrastructure costs are not considered, as they would be incurred by the farmer under both production alternatives and are therefore not relevant for the comparative assessment. Accounting for variable irrigation costs reduces the gross margin advantage of spinach to approximately 250 €/ha. Consequently, the economic advantage of spinach is not substantially affected.

Gross Margins at Crop Rotation Level

Since chickpea achieves a lower gross margin than spinach, the protein crop rotation generates a lower average gross margin than the baseline rotation. The protein crop rotation including chickpea achieves an average gross margin of 714 €/ha, compared to 812 €/ha for the baseline rotation, resulting in an average gross margin difference of -98 €/ha. This reduction is primarily attributable to the replacement of spinach, a high-value irrigated vegetable crop with exceptionally high gross margins. Consequently, the economic benefits of chickpea are insufficient to offset the loss of spinach profitability at the rotation level.

Considerable variation occurs between years. In 2022 and 2024, the protein crop rotation achieves a gross margin disadvantage of 119 €/ha and 391 €/ha, respectively. In contrast, the protein crop rotation outperforms the baseline rotation by 263 €/ha in 2023. This result is associated with above-average chickpea yields and favorable market prices, illustrating the strong influence of annual production conditions on chickpea profitability. Excluding support payments results in only marginal reductions in gross margins and does not substantially alter the relative performance of the two crop rotations.

Overall, the results highlight two important findings. First, chickpea can represent an economically viable crop option at the crop level. Second, the economic attractiveness of integrating chickpea into a crop rotation depends strongly on the profitability of the crop it replaces. In the case of Apulia, replacing a high-margin irrigated spinach crop reduces overall rotation profitability. In practice, chickpeas are therefore unlikely to fully replace spinach. Instead, they are more likely to be introduced on non-irrigated land that is unsuitable for spinach cultivation.

3.2.3. Parity Prices and Sensitivity Analysis

Parity Price Analysis

Using the average chickpea yield of 2.2 t/ha and average direct costs of 675 €/ha, the parity price required to achieve the same gross margin as spinach amounts to 916 €/t when support payments are included. Compared with the average chickpea price of 786 €/t, this corresponds to a required price increase of 17 %. The likelihood of achieving parity with spinach appears limited. Although chickpea prices are relatively stable and exhibit only moderate fluctuations, the highest observed price during the assessment period was 860 €/t in 2023, remaining well below the parity price of 916 €/t. Consequently, achieving spinach-level gross margins through higher chickpea prices alone appears unlikely under average production conditions. Excluding support payments results in slightly higher parity prices; however, the effect is marginal and does not materially alter the overall conclusions.

As chickpea replaces spinach in the protein crop rotation, the parity price at the crop rotation level is identical to the parity price calculated for spinach at the crop level. This result illustrates the economic

challenge of replacing a high-value irrigated vegetable crop with a rainfed protein crop. Under average yield and price conditions, achieving the same gross margin as the baseline rotation is unlikely.

No consistent relationship between chickpea and durum wheat prices is observed during the assessment period (2022: 1:1.51, 2023: 1:2.31, 2024: 1:2.28). This indicates that chickpea prices are linked to different market segments, primarily human food markets, and are therefore not closely aligned with cereal market developments.

Yield Sensitivities

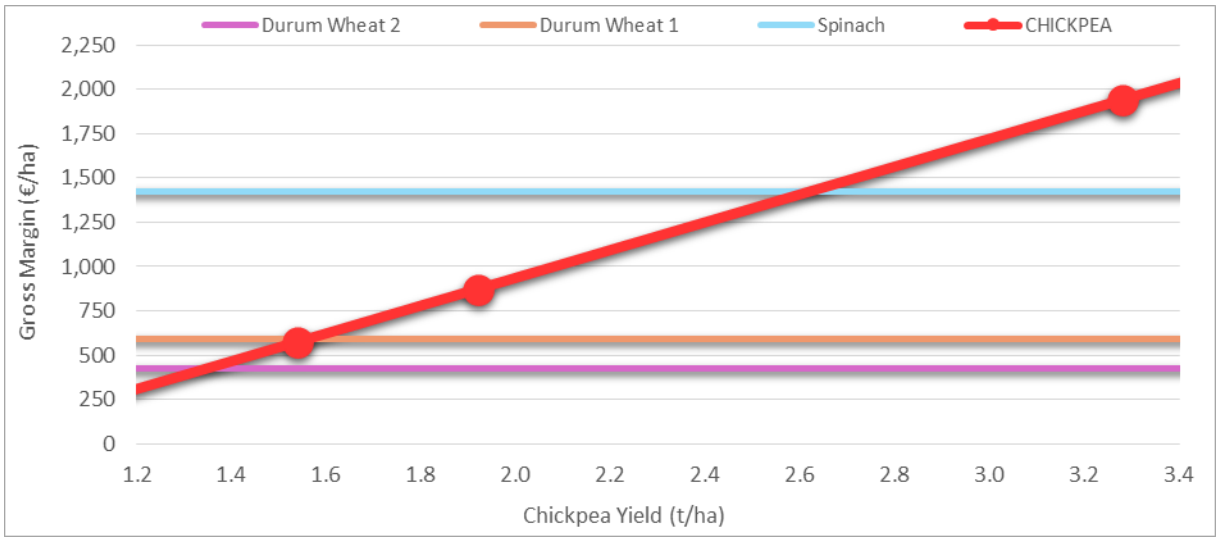


Figure 1: Sensitivity of crop-level gross margins to changes in chickpea yield (including support payments).
Source: *agri benchmark* calculations.

The gross margin analysis showed that chickpea production is characterized by substantially greater yield variability than price variability. Consequently, profitability is influenced more strongly by fluctuations in yield than by changes in market prices. Figure 1 highlights the strong relationship between chickpea yield and economic performance at the crop level. At low yield levels, chickpea remains competitive with durum wheat but does not reach the profitability of spinach. Under favorable growing conditions, however, chickpea achieves gross margins that exceed those of spinach, becoming the most profitable crop among the assessed alternatives. These results demonstrate that yield performance is the key determinant of chickpea profitability. Consequently, genetic improvement aimed at increasing yield potential and enhancing yield stability may support the long-term competitiveness of chickpea production. The implications of yield variability at the crop rotation level are illustrated in Figure 2. While the aggregation of gross margins across the rotation reduces annual fluctuations, only the highest observed chickpea yield enables the protein crop rotation to outperform the baseline rotation. At lower yield levels, the replacement of the high-margin spinach crop results in lower crop rotation gross margins.

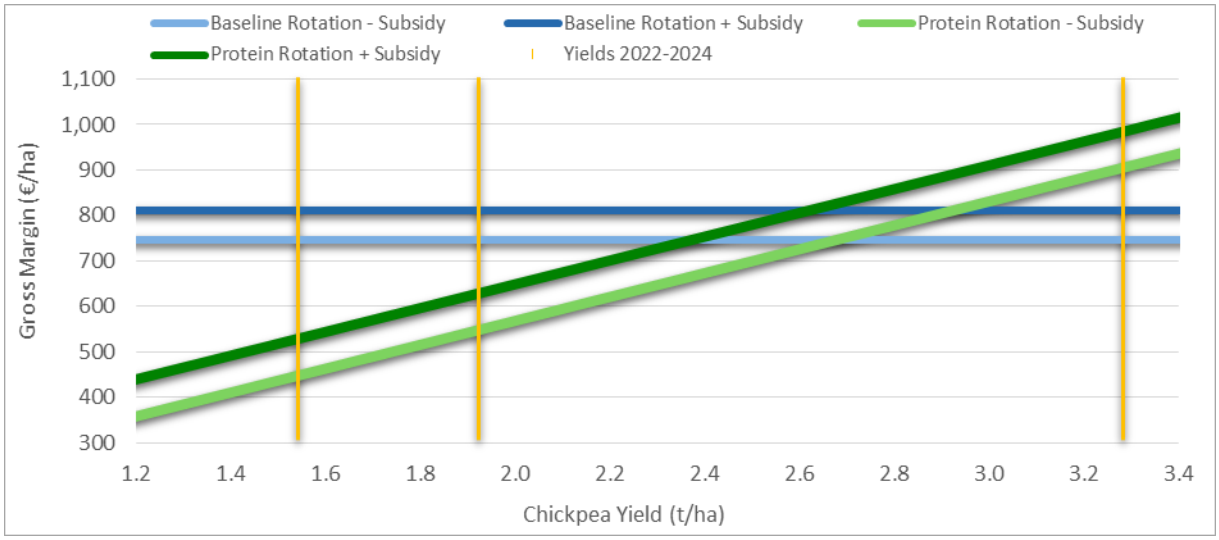


Figure 2: Sensitivity of rotation-level gross margins to changes in chickpea yield.
Source: *agri benchmark* calculations.

Overall, the sensitivity analysis indicates that chickpea remains economically competitive with durum wheat across a broad range of yield levels. However, only exceptionally high yields allow chickpea to outcompete spinach and offset the replacement of the high-margin spinach crop in the protein crop rotation. The high gross margin variability reflects the strong dependence of chickpea profitability on yield performance and market conditions. Yield variability therefore represents both the greatest economic risk and the greatest economic opportunity for chickpea production in the Apulia region.

3.2.4. Additional Considerations for the Economic Viability

In addition to validating the economic analysis of chickpeas and the overall production system, the focus group discussion also provide practical insights into the agronomic, operational, and market-related factors influencing the economic viability of chickpea cultivation in Apulia (see Protocol A-1). While gross margins and crop rotation analyses quantify the economic performance of chickpeas, farmers emphasize that cultivation decisions are influenced by additional aspects that are not fully reflected in gross margins alone.

A central finding of the discussion is the important role of chickpeas within the predominantly durum wheat-based production systems of the region. All participants emphasize that chickpeas represent a valuable option for crop diversification and biological nitrogen fixation. Farmers generally regard chickpeas not only as a cash crop but also as an option to improve soil fertility and the long-term sustainability of the production system. Chickpeas are typically grown in rotations such as durum wheat–durum wheat–chickpea. Although positive crop rotation effects are commonly reported in the literature, farmers indicate that the benefits on subsequent crop yields and nitrogen requirements are generally smaller and less tangible than often assumed. Soil analyses are not routinely conducted, making it difficult to quantify crop rotation effects accurately. In addition, the high variability of climatic conditions between years can mask or distort crop rotation effects and complicate their attribution to individual agronomic factors.

The discussion further indicates that chickpea cultivation is technically feasible under regional conditions. Farmers report no major challenges regarding seed availability, sowing operations, or harvesting. Harvesting is generally regarded as straightforward, provided that appropriate grain moisture levels are achieved. Consequently, no substantial operational barriers are identified that would impede a wider adoption of chickpea cultivation.

However, participants identify several agronomic and market-related risks that influence the economic attractiveness of chickpeas. Agronomic management, particularly weed, disease, and pest control, remains a challenge for achieving stable yields. Yield variability is repeatedly highlighted as a major challenge, which is consistent with the results of the sensitivity analysis. Marketing is typically organized through cooperatives, with the possibility of establishing forward contracts prior to sowing. Such arrangements are used particularly in smaller and more specialized markets, including chickpeas, where they can help secure market access and reduce marketing risks. In addition, market requirements play an important role in determining economic performance. Since chickpeas are produced for human consumption, quality standards regarding moisture content, grain size, and visual appearance must be met. Compliance with these quality requirements depends on appropriate variety selection, good agronomic practices throughout the growing season, and careful harvest and post-harvest management. Farmers highlight the importance of consistently achieving marketable quality and securing access to suitable marketing channels.

Although chickpeas receive governmental support payments, farmers generally state that support payments are not the primary driver of cultivation decisions. Instead, the agronomic benefits of crop rotations, gross margins, and market opportunities are identified as the main determinants. This finding supports the results of the gross margin and sensitivity analyses, which show that support payments have only a limited influence on overall profitability compared to yields and market prices.

Regarding future development, farmers express a generally positive attitude towards chickpea cultivation. Nevertheless, the expansion of chickpea production is expected to depend largely on economic competitiveness and the availability of attractive market opportunities. Several participants indicate that chickpeas compete primarily with other rainfed crops, whereas irrigated crops remain economically more attractive where sufficient water is available. This observation is consistent with the economic analysis, which identifies the replacement of high-value irrigated spinach as the main factor limiting the profitability of the protein crop rotation. Participants highlight targeted incentives, support for crop rotation schemes, and greater recognition of the agronomic value of protein crops as important measures to encourage adoption. In particular, the contribution of chickpeas to soil fertility and biological nitrogen fixation is seen as a benefit that is not fully captured by economic indicators.

Overall, the focus group discussion confirms that chickpea cultivation is agronomically feasible within durum wheat-based farming systems in Apulia. The results further suggest that the main challenge is not crop establishment or management, but rather achieving sufficiently stable yields and attractive crop prices through well-established markets.

3.3. Lupin Cultivation in Western Pomerania, Germany

3.3.1. Regional Context and Cropping Systems

Lupin Cultivation in Germany

The average cultivation area of lupins in Germany amounted to approximately 27,730 ha during the period 2022–2024 and remained relatively stable over recent years (Destatis, 2026). Lupin cultivation in Germany is concentrated in the northeastern federal states, particularly Brandenburg (28 % of the national cultivation area) and Mecklenburg-Vorpommern (21 %), which also exhibit the highest shares of lupins in total arable land (0.8 % and 0.5 %, respectively) (Destatis, 2026b). Owing to its importance for German lupin production, both in terms of cultivation area and the relative share of lupins in arable land, the region of Western Pomerania in Mecklenburg-Vorpommern serves as the representative region for the assessment of lupin cultivation in Germany.

Regional Conditions in Western Pomerania

Western Pomerania is located in northeastern Germany and is characterized by a temperate maritime climate with a mean annual temperature of approximately 9.5 °C. Average annual precipitation amounts to approximately 600 mm (Copernicus Climate Change Service, 2026), with periods of water scarcity frequently occurring during spring and early summer. Soils are predominantly light-textured, consisting mainly of loamy sands and sandy loams with low water-holding capacity. These conditions favor drought-tolerant crops such as lupins and make yield performance strongly dependent on rainfall availability.

Characteristics of Lupin Cultivation

Lupin (*Lupinus* spp.) is a grain legume adapted to temperate climates and is well suited to sandy, low-fertility soils (see Profile A-2). It is sensitive to drought stress during flowering and generally unsuitable for waterlogged or compacted soils (GFL, 2025). Its deep taproot contributes to improved soil structure and efficient resource use (Alpmann & Schäfer, 2014). Three lupin species are commonly distinguished in European agriculture: yellow lupin (*Lupinus luteus*), narrow-leafed lupin (*Lupinus angustifolius*), and white lupin (*Lupinus albus*). In Germany, white lupin cultivation has increased in recent years following the introduction of anthracnose-tolerant varieties, which are tolerant to a major fungal disease of lupin (GFL, 2025). Consequently, the present assessment focuses on white lupin cultivation. Compared with narrow-leafed lupin, white lupin offers higher yield potential and higher protein concentrations but requires better soil conditions and has a longer growing season (DSV, 2022). Lupin seeds naturally contain alkaloids, bitter compounds that may be toxic to humans and animals at elevated concentrations. Alkaloid content therefore represents an important quality attribute, particularly for food applications. Lupins are also classified as a mandatory allergen under European food labeling regulations (GFL, 2025). With protein concentrations of up to 38 %, lupins have one of the highest protein contents among grain legumes and are exceeded only by soybean (Sinkovič et al., 2023). Lupins are used for animal feed, human consumption, and seed production. Their high protein content and favorable processing characteristics have contributed to growing interest in food applications in recent years (GFL, 2025).

Crop Rotations in Western Pomerania

The baseline rotation in the Western Pomerania region is defined as a four-year crop rotation consisting of winter barley, winter oilseed rape, winter wheat, and corn silage. Each crop accounts for 25 % of the rotation area. Winter barley, winter oilseed rape, and winter wheat are among the dominant crops in the region, whereas corn silage is primarily produced for dairy production and biogas generation. To integrate lupin as a protein crop in the rotation, the baseline rotation is extended to a five-year rotation. Lupins are positioned after corn silage, which leaves only limited amounts of residual soil nitrogen. The subsequent crop after lupin is winter barley, which is able to utilize the nitrogen fixed by lupin. To ensure an adequate cultivation break between protein crops, lupin accounts for 10 % of the total rotation area, while the shares of the remaining crops are reduced proportionally to approximately 23 % each.

3.3.2. Gross Margin Analysis

Yields and Prices

During the period from 2022 to 2024, lupin yields in the assessment range from 2.9 to 4.4 t/ha, with a three-year average of 3.5 t/ha (see Table A-2). Relative to the average yield (100 %), annual yields vary between 85 % and 128 %. In comparison, winter oilseed rape exhibits a lower degree of yield variability, ranging from 90 % to 111 % of its average yield, while variability is even lower for winter

barley, winter wheat, and corn silage (97–104 %). The comparatively high yield variability of lupin indicates a greater production risk than for the competing crops and suggests that annual growing conditions play an important role in determining lupin profitability.

Price variability is lower than yield variability for lupin. The average lupin price amounts to 317 €/t and ranges from 270 to 381 €/t, corresponding to 85–120 % of the three-year average price. The observed market prices primarily reflect feed-market conditions, as most lupins are marketed as animal feed. Lupins destined for human consumption achieve higher prices, depending on quality requirements, processing characteristics, and end use (see complementary work in VPP Deliverable 5.4, Annex 6). In contrast, price variability exceeds yield variability for most competing crops. Winter barley shows the highest price variability, ranging from 82 % to 121 % of its average price, while price fluctuations for winter wheat, winter oilseed rape, and corn silage are more moderate (91 % to 114 %).

Overall, the results suggest that lupin profitability is influenced more strongly by yield fluctuations than by changes in observed market prices. In contrast, market price developments play a relatively larger role in determining the economic performance of the competing crops. Consequently, improving yield stability appears to be a key factor in enhancing the economic competitiveness of lupin production in Western Pomerania.

Revenues and Costs

Positive crop rotation effects of lupin cultivation are well documented in the literature. During the focus group discussion, the following assumptions were discussed and agreed upon for the assessment. First, a yield increase of 0.5 t/ha for the subsequent winter barley is assumed. In addition, nitrogen fertilizer savings of 20 kg N/ha in the winter barley are taken into account. Reductions in pesticide expenditures, resulting either from lower pesticide use or the replacement of plant protection products with less costly alternatives in the crop rotation, are quantified at 25 €/ha. Together, these effects result in an average crop rotation effect of 155 €/ha attributable to lupin cultivation, ranging from 133 to 174 €/ha between years. Yield gains account for the largest share of the crop rotation effect (67 %), whereas nitrogen fertilizer savings (17 %) and reductions in pesticide expenditures (16 %) contribute to a lesser extent. These results suggest that crop rotation effects can make an important contribution to the economic performance of lupin cultivation.

Average revenues for lupin amount to 1,853 €/ha (1,639–1,931 €/ha) during the assessment period. Lupin revenues consist of three components: revenues from the main product (60 %), crop rotation effects (8 %), and governmental support payments (32 %). The support payment is linked to the CAP scheme promoting diversified crop rotations. Eligibility requires a minimum of five crops on the farm with cultivation shares between 10 % and 30 %, at least one legume crop, and a maximum cereal share of 66 % (excluding corn). The support payment amounts to 60 €/ha for all crops included in the diversified rotation (BMLEH, 2026). For the representative farm considered in this assessment, the inclusion of a legume crop with a minimum share of 10 % is the only additional requirement for compliance with the diversification scheme. Therefore, the entire payment is allocated to lupin cultivation, resulting in support payments of 600 €/ha of lupin area. Although this assumption may not apply to all farms, many farms in the region already maintain relatively diversified crop rotations due to agronomic constraints, including weed pressure in winter crops and limited insecticide availability in winter oilseed rape. Consequently, support payments represent a substantial share of total lupin revenues. Winter wheat (1,872 €/ha) and winter oilseed rape (1,944 €/ha) generate higher revenues than lupin. In contrast, lupin revenues exceed those of winter barley (1,628 €/ha) and corn silage (1,377 €/ha). For the competing crops, only revenues from the main product are considered.

Although lupin does not generate the highest revenues, it achieves a revenue level comparable to that of winter wheat.

Lupin records the lowest direct costs among all assessed crops, averaging 359 €/ha (319–429 €/ha). These costs are mainly attributable to seeds (56 %), pesticides (23 %), and fertilizers (21 %), indicating that seed costs are the dominant cost component of lupin production. Winter oilseed rape has the highest average direct costs at 663 €/ha, followed by winter wheat (599 €/ha), winter barley (545 €/ha), and corn silage (419 €/ha). For all competing crops, fertilizer expenditures represent the main cost driver, followed by pesticides and seeds. In contrast, the comparatively low fertilizer requirements of lupin, resulting from biological nitrogen fixation, contribute substantially to its low cost structure. Regarding cost variability, lupin exhibits a narrower range (89–120 % of the three-year average) than winter wheat, winter oilseed rape, and winter barley (together 82–129 %), but slightly higher variability than corn silage (88–112 %).

Gross Margins at Crop Level

In the scenario including support payments, lupin achieves the highest average gross margin among the assessed crops, amounting to 1,494 €/ha (1,320–1,594 €/ha). The remaining crops rank as follows: winter oilseed rape (1,281 €/ha), winter wheat (1,274 €/ha), winter barley (1,083 €/ha), and corn silage (958 €/ha). Despite generating lower revenues than winter oilseed rape and winter wheat, lupin achieves the highest gross margin due to the combined effect of comparatively low direct costs, positive crop rotation effects, and support payments. Consequently, lupin is highly competitive at the crop level when support payments are included.

The economic ranking changes substantially when support payments are excluded. In this scenario, the average gross margin of lupin declines to 894 €/ha (720–994 €/ha), falling below that of corn silage and making lupin the least profitable crop. This result highlights the importance of support payments to the economic competitiveness of lupin production. While lupin ranks as the most profitable crop when support payments are included, it becomes the least profitable option in their absence.

The variability in gross margins for lupin ranges from 88 % to 107 %, indicating a comparatively moderate level of economic risk. This relatively stable economic performance is likely supported by the contribution of crop rotation effects and support payments to total lupin revenues. Among the competing crops, winter barley, winter oilseed rape, and winter wheat exhibit substantially greater variability in gross margins (75–144 %). In contrast, corn silage shows only limited gross margin variability (96–102 %), reflecting a comparatively stable economic performance.

It is also noteworthy that the difference in gross margins between the most profitable competing crop, winter oilseed rape, and the least profitable competing crop, corn silage, amounts to approximately 320 €/ha. Despite this considerable difference in gross margins, all crops remain part of existing crop rotations. This indicates that cropping decisions are not driven solely by crop-level gross margins but are also influenced by agronomic considerations, crop rotation requirements, risk diversification, and operational factors.

Gross Margins at Crop Rotation Level

Comparing the average gross margin of the protein crop rotation (1,184 €/ha) with the gross margin of the baseline rotation (1,149 €/ha), the inclusion of lupin increases the average gross margin by 35 €/ha when support payments are included. In contrast, excluding support payments results in a reduction of 25 €/ha compared to the baseline rotation. These results highlight the considerable influence of support payments on the economic competitiveness of the protein crop rotation with lupin.

The economic advantage or disadvantage of the protein crop rotation varies between years but does not affect the relative ranking of the rotations. With support payments, the protein crop rotation consistently generates higher gross margins than the baseline rotation, with annual advantages ranging from 8–52 €/ha. Without support payments, this relationship reverses, and the baseline rotation outperforms the protein crop rotation by between 8–52 €/ha across the assessed years. While support payments generate a consistent advantage over the baseline rotation, lupin cultivation does not improve crop rotation profitability under market conditions alone.

It should also be considered that an average gross margin increase of 35 €/ha is relatively small compared to the risks and efforts associated with introducing a new crop into an existing farming system. The adoption of lupin requires additional knowledge, experience, marketing contacts, and adjustments to farm management. Therefore, a gross margin advantage of 35 €/ha may not provide a sufficiently strong economic incentive for farmers to expand lupin cultivation and reduce the area devoted to established crops. On the other hand, extending the crop rotation helps break weed, pest, and disease cycles and may provide additional agronomic benefits through improved crop health and reduced production risks, which are not reflected in the economic analysis. Furthermore, the oversubscription of state-level support programs promoting legume cultivation within diversified crop rotations indicates strong farmer interest in this concept.

3.3.3. Parity Prices and Sensitivity Analysis

Parity Price Analysis

For the parity price analysis, an average lupin yield of 3.5 t/ha, average direct costs of 359 €/ha, and average crop rotation effects of 155 €/ha are taken into account. In the scenario excluding support payments, the parity price regarding corn silage amounts to 336 €/t, corresponding to a price increase of 6 % relative to the average observed lupin price (317 €/t). Even if higher price levels were already observed in 2022, when lupin prices reached 381 €/t, an increase in average prices under current feed-market conditions appears unlikely. However, the increasing use of lupins for human consumption provides opportunities to access higher-value markets and achieve significantly higher prices.

When support payments are included, lupin achieves the highest gross margin among all assessed crops, and parity prices decline considerably. To achieve the same profitability as winter oilseed rape, the next most profitable crop, the lupin price could decline by 19 % to 256 €/t. These results indicate the considerable economic buffer between lupin and the competing crops under the support payment scenario. This substantial buffer is largely explained by the combined contribution of support payments and crop rotation effects to lupin gross margins.

At the crop rotation level, the parity price required for lupin to achieve the same gross margin as the baseline rotation amounts to 391 €/t when support payments are excluded, corresponding to a price increase of 23 %. This parity price exceeds the highest observed lupin price during the assessment period (381 €/t), indicating that the profitability advantage of the protein crop rotation cannot be achieved under current market conditions alone. In contrast, when support payments are included, the lupin price could decline by 31 % to 217 €/t while still maintaining the profitability advantage of the protein crop rotation. This finding highlights the important role of support payments in the economic performance of lupin cultivation.

The relationship between winter wheat and lupin prices remains remarkably stable throughout the assessment period, averaging 1:1.27 and ranging from 1:1.18 to 1:1.33. This suggests that lupin and wheat markets are closely linked and that lupin prices largely follow developments in wheat markets. The average price ratio of 1.27 falls within the range of 1:1.20–1.30, which was identified during the

focus group discussion as the typical long-term price relationship between wheat and protein crops used for feed. This finding confirms that the observed lupin price level is consistent with feed use. Consequently, wheat price trends may provide a useful indicator of future price developments for feed lupins.

Yield Sensitivities

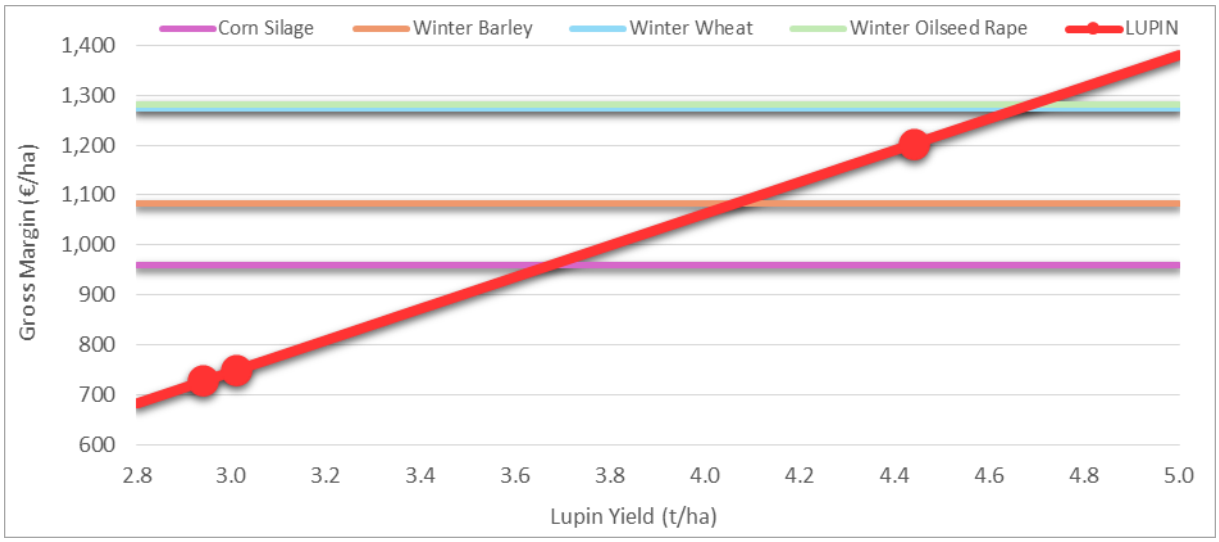


Figure 3: Sensitivity of crop-level gross margins to changes in lupin yield (excluding support payments).
Source: *agri benchmark* calculations.

As yield variability was identified as the main production risk in lupin cultivation, the sensitivity analysis examines how changes in lupin yield affect economic performance at both the crop and crop rotation levels under different support payment scenarios. Figure 3 illustrates the relationship between lupin yield and crop-level gross margins in the scenario without support payments. The relatively high yield variability has a pronounced effect on the economic performance of lupins. At low yield levels, lupin generates lower gross margins than winter barley and corn silage. As yields increase, the competitiveness of lupin improves considerably, enabling it to reach gross margins comparable to those of these crops. However, even at the highest observed yield levels, lupins do not achieve gross margins comparable to those of winter wheat or winter oilseed rape. Figure 4 indicates that yield effects are less pronounced at the crop rotation level because gross margins are averaged across all crops in the rotation. Without support payments, only the highest observed yields generate a slight profitability advantage over the baseline rotation. In contrast, when support payments are included, the protein crop rotation consistently outperforms the baseline rotation across the entire observed yield range.

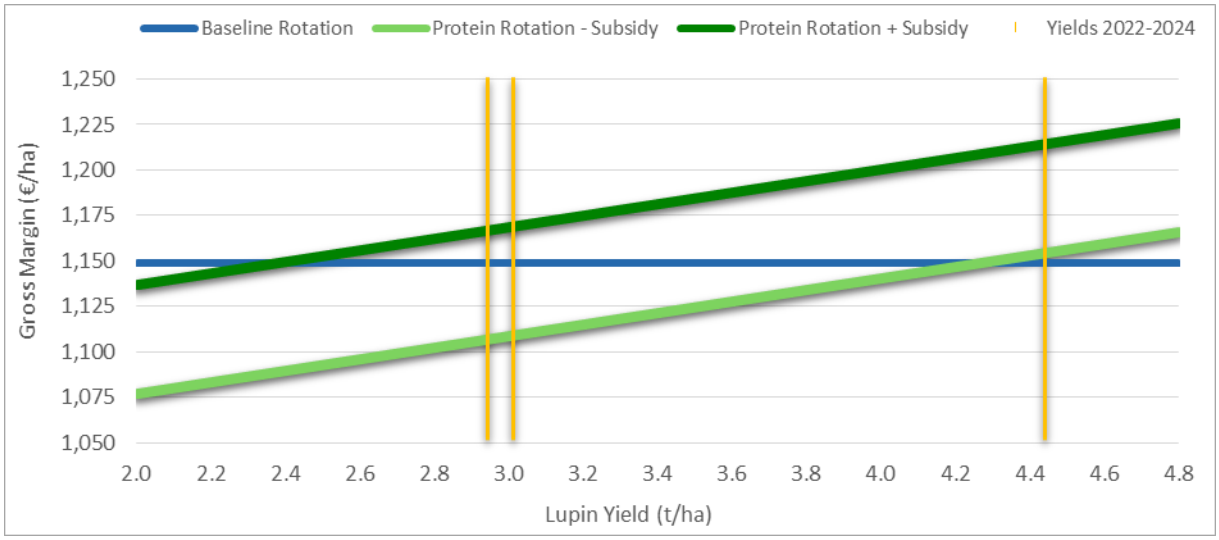


Figure 4: Sensitivity of rotation-level gross margins to changes in lupin yield.
Source: *agri benchmark* calculations.

Overall, the sensitivity analysis indicates that lupin profitability is sensitive to yield fluctuations, particularly in the absence of support payments. While yield improvements strengthen the competitive position of lupin, they are insufficient to outperform the most profitable crops under current market conditions. Crop rotation effects and support payments make an important contribution to gross margins, supporting the economic competitiveness of lupin across a wide range of production conditions and enabling consistent improvements in crop rotation profitability when support payments are included.

3.3.4. Additional Considerations for the Economic Viability

The focus group discussion provides important insights to validate and complement the quantitative economic analysis and help explain the observed economic performance of lupin cultivation in northeastern Germany (see Protocol A-2). Overall, the discussion confirms that the economic value of lupins extends beyond conventional crop-level gross margins. Positive crop rotation effects, governmental support payments, and the use of lupins as an on-farm protein feed source emerge as the main factors supporting their economic viability.

A key motivation for cultivating lupins is their use as a protein source for livestock feeding. Farmers highlight that lupins enable non-genetically modified organism (non-GMO) feeding systems, which enable higher milk prices. Participants also emphasize the benefits of lupins within crop rotations. Reported crop rotation effects include increased winter barley yields following lupin compared with corn silage, reduced nitrogen fertilizer requirements in subsequent winter barley, reduced plant protection expenditures within the crop rotation, improvements in soil structure, and lower seedbed preparation requirements. Although some of these benefits, particularly improvements in soil structure, are difficult to quantify economically, they are nevertheless considered important advantages of lupin cultivation.

Despite these benefits, several agronomic challenges limit the attractiveness of lupin production. Weed control is identified as a major constraint because of the crop's slow early growth and the limited availability of effective post-emergence herbicides. Consequently, successful cultivation depends on optimized crop establishment and effective weed management. Yield instability due to weather constraints represents another major challenge. High seed costs are also regarded as a significant barrier to adoption. Furthermore, farmers report that the late maturity of white lupins in

September often coincides with other labor-intensive field operations and may delay the establishment of subsequent autumn-sown crops.

While participants generally consider agronomic challenges manageable through appropriate management practices, market-related constraints are viewed as the more significant obstacle to expanding lupin cultivation. Most participating farms use lupins primarily for on-farm feeding, whereas sales to external markets remain limited. Farmers cite uncertain market prospects, limited demand, and a lack of reliable marketing channels as major concerns. Additional barriers include restrictions related to alkaloid content, allergen labeling requirements, quality specifications for food applications, and the relatively small market size, which increases storage and handling costs. Participants note that feed manufacturers often favor established protein feed sources even when lupins are available at competitive prices. Quality requirements vary according to the intended use and may include limits on alkaloid content, specific seed color and shape characteristics, and thresholds for insect damage. Meeting these standards depends on appropriate variety selection and sound agronomic management.

The discussion also highlights the importance of support payments. Farmers indicate that lupins remain an important component of their cropping systems because of their benefits for livestock feeding and crop rotation management. Nevertheless, several participants explicitly state that current profitability would be difficult to sustain without policy support. In their view, lupin cultivation is economically viable primarily when both crop rotation effects and support payments are taken into account. This finding is consistent with the quantitative economic analyses, which identify support payments as a major determinant of lupin competitiveness.

Regarding future development, participants expect the area under lupin cultivation to remain relatively stable. Expansion potential is considered limited due to uncertain market demand. The measures most frequently suggested to support lupin production include breeding efforts aimed at improving yield stability and reducing alkaloid content, greater research and extension activities addressing crop rotation effects, the development of reliable market outlets for feed and food applications, and the continuation of agri-political support measures for protein crop cultivation.

Overall, the focus group discussion confirms that lupins provide substantial benefits at the crop rotation level and can compete with conventional crops when crop rotation effects are considered and support payments are in place. However, limited market opportunities, yield instability, and weed management challenges continue to restrict the wider adoption of lupins in the region.

3.4. Pea Cultivation in Funen, Denmark

3.4.1. Regional Context and Cropping Systems

Pea Cultivation in Denmark

In Denmark, pea cultivation has shown considerable fluctuations over the past two decades. Following a pronounced decline from approximately 40,400 ha in 2002, the cultivation area remained relatively stable at around 5,500 ha between 2008 and 2019. Thereafter, the area increased substantially, reaching 19,400 ha in 2023, before declining again to 8,700 ha in 2025 (Eurostat, 2026). These developments are closely linked to changing policy frameworks and market conditions. During the period 2022–2024, the largest share of the national pea area was located in the region of Southern Denmark (31 %), followed by Zealand (23 %), Central Denmark (23 %), and North Denmark (18 %). Across the main production regions, peas account for between 0.7 % and 1.0 % of total arable land. Within Southern Denmark, the island of Funen accounts for approximately 13 % of the national pea

cultivation area. Peas occupy around 1.2 % of the total arable land on the island (Statistics Denmark, 2026). Given its comparatively large cultivation area and its importance for pea production, Funen is selected as the representative region for the assessment of pea cultivation in Denmark.

Regional Conditions in Funen

The region of Funen is an island located in central Denmark and is characterized by a temperate maritime climate that provides favorable conditions for pea cultivation. The mean annual temperature is approximately 9 °C, while average annual precipitation amounts to around 650 mm (Copernicus Climate Change Service, 2026). The predominantly clay-based soils are generally fertile, with good nutrient retention and water-holding capacity. Overall, the combination of moderate temperatures, sufficient rainfall, and productive soils makes Funen a suitable region for pea production.

Characteristics of Pea Cultivation

Pea (*Pisum sativum* L.) is a cool-season grain legume adapted to temperate climatic conditions (see Profile A-3) (Macák et al., 2020). The crop performs best under moderate temperatures and adequate soil moisture during flowering and grain filling, while drought stress can substantially reduce yields. Peas are best suited to well-drained loamy or sandy-loam soils and are sensitive to waterlogging and soil compaction due to their relatively shallow root system (Stoddard et al., 2022; Stoddard & Schauman, 2022). Peas are utilized for animal feed, human consumption, and seed production, with feed use currently representing the dominant market outlet in Denmark. However, demand from the food sector has increased in recent years due to the growing market for plant-based protein products (Stoddard et al., 2022). Pea seeds typically contain around 19 % protein and are characterized by a high starch content (Sinkovič et al., 2023), making them a valuable source of both protein and energy in feed and food applications.

Crop Rotations in Funen

In the Funen case study, six different crops are cultivated, with some crops occurring more than once within the sequence. Because crop shares differ substantially due to agronomic and contractual requirements, the same sequence of crops cannot be implemented on every field. Consequently, the system is more appropriately described as a crop sequence rather than a conventional crop rotation, as individual crops occur at different frequencies and intervals within the overall cropping system. Nevertheless, for consistency with the other case studies, the terms baseline rotation and protein crop rotation are retained throughout the analysis.

The crop sequence begins with spring barley, followed by a second consecutive spring barley. During the seeding of the second spring barley, red fescue seed is established as an undersown crop and continues its growth after barley harvest. Red fescue seed is harvested for seed production in two consecutive years. Following the two years of red fescue seed production, winter oilseed rape, winter wheat, spinach seed, and a second winter wheat are cultivated. Both red fescue seed and spinach seed production are based on contracts. Danish regulations require winter soil cover through either winter crops or cover crops in order to reduce nutrient losses and protect the soil during winter. Furthermore, cover crops must account for at least 50 % of the farm area. Consequently, cover crops are established after spring barley and after both winter wheat crops. The assessment focuses on the economic performance of peas and the competing main crops; therefore, cover crop costs are assumed to affect both rotation scenarios equally and are excluded from the analysis. Within the baseline rotation, winter wheat represents the largest share of the rotation area (17 % each), followed by the first spring barley (16 %), the second spring barley and winter oilseed rape (12 % each), both red fescue seeds (9 % each), and spinach seed (8 %).

To integrate pea as a protein crop, the sequence is extended by pea and a subsequent winter wheat. Pea is introduced after the second winter wheat and the subsequent cover crop. In accordance with Danish regulations, a winter crop must follow a protein crop in order to utilize the residual nitrogen remaining after biological nitrogen fixation. Therefore, pea is followed by winter wheat, which is subsequently followed by a cover crop. Pea accounts for 8 % of the farm acreage, ensuring sufficient cultivation breaks between protein crops. The area devoted to spinach seed remains unchanged due to existing contracts and its high profitability. Similarly, the share of winter oilseed rape remains constant because of its strong economic performance. With the addition of a third winter wheat, the overall share of winter wheat remains unchanged, with the first two winter wheat crops each accounting for 13 % of the rotation area and the wheat crop following pea accounting for 8 %. To maintain the required share of cover crops, the area of the first spring barley remains unchanged. The areas allocated to both red fescue seeds are reduced slightly to 8 % each, while the largest reduction occurs in the second spring barley crop, whose share decreases to 6 % because of its comparatively lower profitability.

3.4.2. Gross Margin Analysis

Yields and Prices

Average pea yields amount to 3.1 t/ha over the assessment period, with annual values ranging from 2.2 to 4.2 t/ha (see Table A-3). Relative to the three-year average, yields fluctuate between 72 % and 135 %. This variability exceeds that of most competing crops, including winter wheat, winter oilseed rape, red fescue seed, and spring barley. Among the competing crops, red fescue seed (86–123 %) and spring barley (74–127 %) also exhibit comparatively high yield variability, reflecting the sensitivity of crop production in the region to annual growing conditions. Spinach seed production exhibits even greater yield variability than pea production, ranging from 40 % to 171 % of the average yield. Identical yields are assumed for both years of red fescue seed production, as yields in the second production year may be either higher or lower than in the first year depending on weather conditions. Consequently, peas and spinach seed rank among the crops with the highest yield fluctuations, indicating that yield variability represents a major production risk and a key determinant of economic performance.

Price variability is generally lower than yield variability for the assessed crops except for winter oilseed rape. The average pea price amounts to 392 €/t and ranges from 362 to 449 €/t, corresponding to 92–114 % of the three-year average price. According to the expert discussion, the comparatively high price level suggests that a share of pea production is marketed for food applications. Although most peas in Denmark are used as animal feed, access to higher-value food markets contributes to the observed price premium. This aspect should be considered when interpreting the economic results. Price variability for the competing crops is of a similar magnitude, ranging between 85 % and 117 % of average prices. Spring barley exhibits the lowest price variability, whereas spinach seed shows the highest price fluctuations. For all assessed crops except winter oilseed rape, yield variability exceeds price variability, suggesting that annual production conditions have a greater influence on economic performance than market price developments. Consequently, yield stability is a key determinant of the competitiveness of pea cultivation in Funen.

Revenues and Costs

Positive crop rotation effects of pea cultivation are well documented in the literature and were discussed in the expert discussion. Based on the expert discussion, a yield increase of 1.3 t/ha and nitrogen fertilizer savings of 15 kg N/ha are assumed for the subsequent winter wheat. Together, these effects result in an average crop rotation effect of 345 €/ha, ranging from 306 to 384 €/ha across

the assessed years. The crop rotation effect is dominated by the yield increase, which accounts for 92 % of the total benefit, while nitrogen fertilizer savings contribute the remaining 8 %. These results highlight the substantial agronomic value of peas within the crop rotation.

Peas generate average revenues of 1,639 €/ha (1,238–2,336 €/ha). In addition to revenues from the main product (74 %), crop rotation effects (21 %) and governmental support payments (5 %) contribute to total revenues. The support payment is linked to the CAP and is granted when protein crops and eligible crops intended for human consumption account for at least 5 % of the total cultivated area. In the assessed sequence, both peas and spinach seed production contribute to fulfilling this requirement. The support payment amounts to approximately 87 €/ha (Danish Agricultural Agency, 2026). Consequently, pea revenues are primarily determined by yield performance and market prices, while crop rotation effects and support payments provide additional income. Among the assessed crops, spinach seed (2,414 €/ha), winter oilseed rape (2,141 €/ha), and winter wheat (2,027 €/ha) generate higher average revenues than peas. In contrast, revenues from red fescue seed (1,590 €/ha) and spring barley (1,448 €/ha) remain below those of peas. For spinach seed, revenues from the main product are supplemented by the support payments. Additional revenues from by-products contribute only marginally to total revenues for winter wheat, spring barley, and winter oilseed rape.

Among all assessed crops, peas record the lowest average direct costs of 330 €/ha (296–376 €/ha). Pesticides represent the largest cost category (42 %), followed by seed costs (38 %), fertilizers (11 %), and miscellaneous costs (9 %). Cost variability ranges from 90 % to 114 % of the three-year average and is lower than for spring barley and winter oilseed rape, but higher than for spinach seed, winter wheat, and red fescue seed. The lowest cost variability is observed for spinach seed (92–106 %), whereas winter oilseed rape exhibits the highest variability (86–118 %). Spinach seed also records the highest average direct costs at 964 €/ha, mainly driven by expenditures for pesticides (38 %), fertilizers (33 %), and miscellaneous costs (29 %). No seed costs occur because the seed company provides the spinach seed. Winter oilseed rape follows with average direct costs of 705 €/ha, followed by winter wheat (679 €/ha), first-year red fescue seed (545 €/ha), spring barley (495 €/ha), and second-year red fescue seed (476 €/ha). As the red fescue seed remains established after the first seed harvest, no additional seed costs occur in the second production year. In addition, pesticide costs are approximately 15 % lower than in the first year. Unlike peas, for which pesticide and seed costs dominate, fertilizer expenditures represent the largest cost component for most competing crops, followed by pesticide costs.

Gross Margins at Crop Level

With support payments included, spinach seed generates the highest average gross margin among the assessed crops (1,451 €/ha). Winter oilseed rape ranks second with a gross margin of 1,436 €/ha, followed by winter wheat (1,349 €/ha). In all three cases, the high gross margins result from a combination of high revenues and high production costs. Peas achieve the next highest gross margin at 1,309 €/ha (922–2,040 €/ha). Their comparatively low direct costs substantially enhance their economic performance. The remaining crops are second-year red fescue seed (1,114 €/ha), first-year red fescue seed (1,045 €/ha), and spring barley (953 €/ha). Although pea gross margins are lower than those of spinach seed, winter oilseed rape, and winter wheat, they outperform both red fescue seeds and spring barley when support payments are included. Peas therefore occupy an intermediate position in terms of economic competitiveness among the assessed crops.

Excluding support payments slightly alters the economic ranking. Winter oilseed rape achieves the highest gross margin, followed by spinach seed (1,364 €/ha). The ranking of the remaining crops

remains unchanged. The gross margin of peas declines to 1,222 €/ha (835–1,953 €/ha), however, it remains below that of winter wheat and above that of second-year red fescue seed. Consequently, peas remain more profitable than both red fescue seed and spring barley, even without support payments. However, they do not reach the profitability levels of the highest-margin crops, namely spinach seed, winter oilseed rape, and winter wheat.

All assessed crops exhibit substantial interannual variability in gross margins due to fluctuations in yields, prices, and costs. For peas, gross margins range from 70 % to 156 % of the three-year average, indicating considerable economic variability. This variability is comparable to that of winter oilseed rape (73–156 %) and slightly higher than that of winter wheat (76–148 %). Red fescue seed and spring barley exhibit even greater variability than peas, with gross margins ranging from 50 % to 167 % of their respective average levels. The highest variability is observed for spinach seed, whose gross margins range from 9 % to 169 % of the average. Although spinach seed generates the highest average gross margin, it is also associated with the greatest economic uncertainty. While peas exhibit substantial gross margin variability, most competing crops show a greater degree of variability.

Several factors help explain the competitiveness of peas. Despite their primary use as animal feed, the expert discussion indicates that part of the pea production is marketed for food applications, contributing to the comparatively high observed prices. Potential market access constraints and quality requirements may limit the realization of such price levels. These aspects are examined in more detail in the expert discussion (3.3.4). Nevertheless, the pronounced variability in both yields and prices represents a significant risk, making economic outcomes highly dependent on annual production and market conditions. The implications of this variability are explored further in the sensitivity analysis (3.4.3). Furthermore, the assumed crop rotation effect of 345 €/ha, primarily driven by an estimated yield increase of 1.3 t/ha in the subsequent winter wheat crop, should be evaluated carefully for individual production systems. The magnitude of the yield effect may vary depending on local soil, climate, and management conditions, and adjustments may therefore be required to reflect site-specific circumstances. The analysis also indicates that the economic position of red fescue seed production has weakened compared with historical levels. According to the expert assessment, red fescue seed production is often considered to be as profitable as winter wheat. Under the assessed conditions, however, gross margins are substantially lower than those of winter wheat. A similar pattern is observed for spring barley, which historically has achieved profitability levels comparable to peas but currently exhibits markedly lower gross margins. These developments may partly reflect lower market prices and increasing production volumes.

Finally, substantial differences in profitability are observed across the assessed crops. While spinach seed is a specialty crop, the difference in gross margin between winter oilseed rape, the most profitable crop, and spring barley, the least profitable crop, amounts to approximately 480 €/ha. Despite these substantial differences in profitability, all crops remain part of the crop rotation.

Gross Margins at Crop Rotation Level

At the crop rotation level, the protein crop rotation achieves an average gross margin of 1,234 €/ha when support payments are included, compared with 1,208 €/ha for the baseline rotation, resulting in an average increase of 26 €/ha. Excluding support payments reduces the advantage of the protein crop rotation to 19 €/ha, however, the difference remains positive. Consequently, the integration of peas improves crop rotation profitability under both scenarios.

The positive effect is observed consistently across all assessed years. When support payments are included, the protein crop rotation outperforms the baseline rotation by 18–34 €/ha. Without support payments, the advantage remains positive but is smaller, ranging from 11–27 €/ha. The comparatively

small difference between the scenarios with and without support payments is primarily attributable to the relatively low support payment level and the limited proportion of subsidized crops within the crop rotation. Support payments are granted only for peas and spinach seed, each accounting for 8 % of the total crop rotation area. As a result, support payments have only a minor influence on crop rotation profitability.

The improved profitability of the protein crop rotation results from both the introduction of peas and the resulting changes in crop allocation within the rotation. By integrating peas, lower-margin crops such as spring barley and red fescue seed are partially displaced while the area of highly profitable crops remains unchanged, contributing to the overall economic improvement of the rotation.

Nevertheless, the practical relevance of the observed economic advantage should be considered. Although the protein crop rotation consistently outperforms the baseline rotation, the average gross margin increase of 19–26 €/ha remains relatively modest. It therefore remains to be seen whether the observed economic benefit alone provides a sufficiently strong incentive to encourage widespread adoption of peas within existing crop rotations, given the absence of additional value opportunities in food markets and the agronomic challenges associated with their cultivation.

3.4.3. Parity Prices and Sensitivity Analysis

Parity Price Analysis

To calculate the parity prices, an average pea yield of 3.1 t/ha, average direct costs of 330 €/ha, and an average crop rotation effect of 345 €/ha are assumed. Including support payments, peas require a price of 405 €/t to achieve the same gross margin as winter wheat, corresponding to a price increase of 3 % relative to the average observed pea price (392 €/t). In 2022, a peak price of 449 €/t was observed. Thus, the parity price required to match the gross margin of winter wheat is close to currently observed market levels. Nevertheless, the expert discussion indicates that such price levels are unlikely to become a stable feature of conventional feed markets. In contrast, access to higher-value markets, particularly human food applications, could substantially improve profitability and may enable peas to achieve gross margins comparable to or exceeding those of winter wheat.

Excluding support payments increases the parity price required to achieve the same profitability as winter wheat to 433 €/t, resulting in a price increase of 10 %. Thus, the exclusion of support payments reduces pea competitiveness relative to winter wheat.

At the crop rotation level, the parity price required for peas to achieve the same profitability as the baseline rotation amounts to 287 €/t when support payments are included. This corresponds to a potential price decline of 27 % relative to the observed average price. When support payments are excluded, the parity price increases to 315 €/t, allowing a price reduction of approximately 20 % while maintaining parity with the baseline rotation. These results indicate a considerable economic resilience of the protein crop rotation. They also reflect the structural adjustments incorporated into the protein crop rotation, particularly the targeted integration of peas into the existing cropping system and the reduction of less profitable crops

The relationship between winter wheat and pea prices remains relatively stable throughout the assessment period. The price ratio ranges from 1:1.41 to 1:1.48, with an average ratio of 1.45. This rather high and stable ratio suggests a close connection between wheat and pea markets. However, the observed price ratio exceeds the range of 1:1.20 – 1.30 between wheat and feed protein crops expected in the expert discussion. This finding is consistent with the expert discussions, which

indicated that a share of pea production is marketed for human food applications rather than exclusively as animal feed, thereby contributing to the comparatively high observed pea prices.

Yield Sensitivities

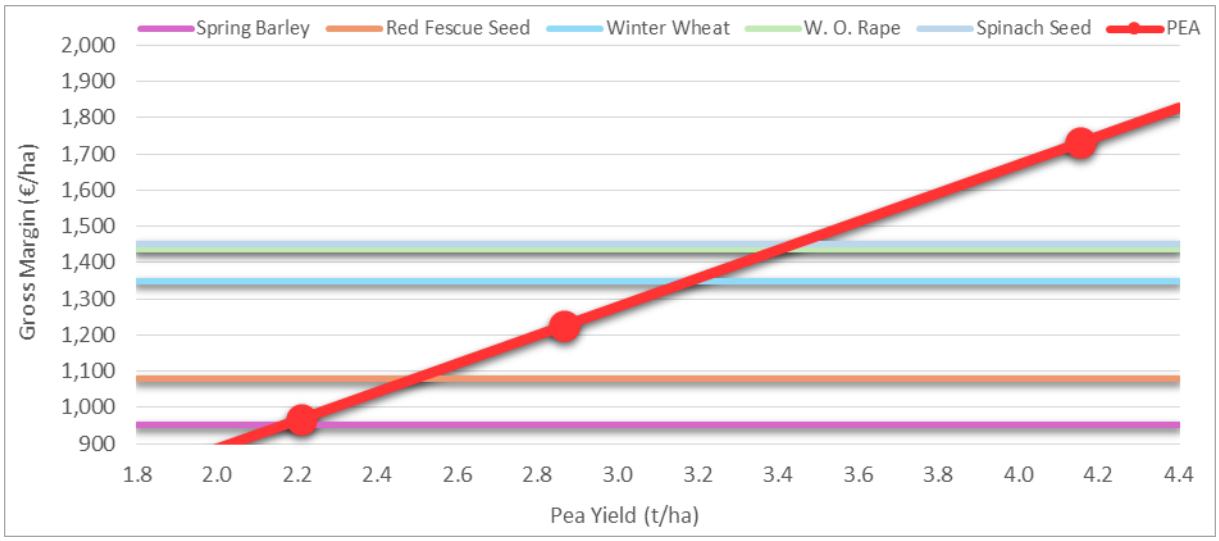


Figure 5: Sensitivity of crop-level gross margins to changes in pea yield (including support payments), "Red Fescue Seed" represents the average of the first and second red fescue seed.
Source: *agri benchmark* calculations.

The gross margin analysis demonstrates that yield variability has a considerably greater influence on economic performance than price variability for peas. At low yield levels, pea gross margins are comparable to those of spring barley but remain below those of red fescue seed (Figure 5). As yields increase, pea profitability improves substantially, exceeding the gross margins of spring barley and red fescue seed under average conditions and surpassing all assessed crops at high yield levels. These results underline the importance of yield performance as a key determinant of pea profitability and a major source of economic risk. At the crop rotation level, higher pea yields increase the profitability of the protein crop rotation relative to the baseline rotation (Figure 6). With support payments, the protein crop rotation remains more profitable across the entire yield range considered. Without support payments, profitability is lower than the baseline rotation at very low pea yields but exceeds it at average yield levels. Increasing pea yields further improve crop rotation profitability and widen the economic advantage of the protein crop rotation over the baseline rotation.

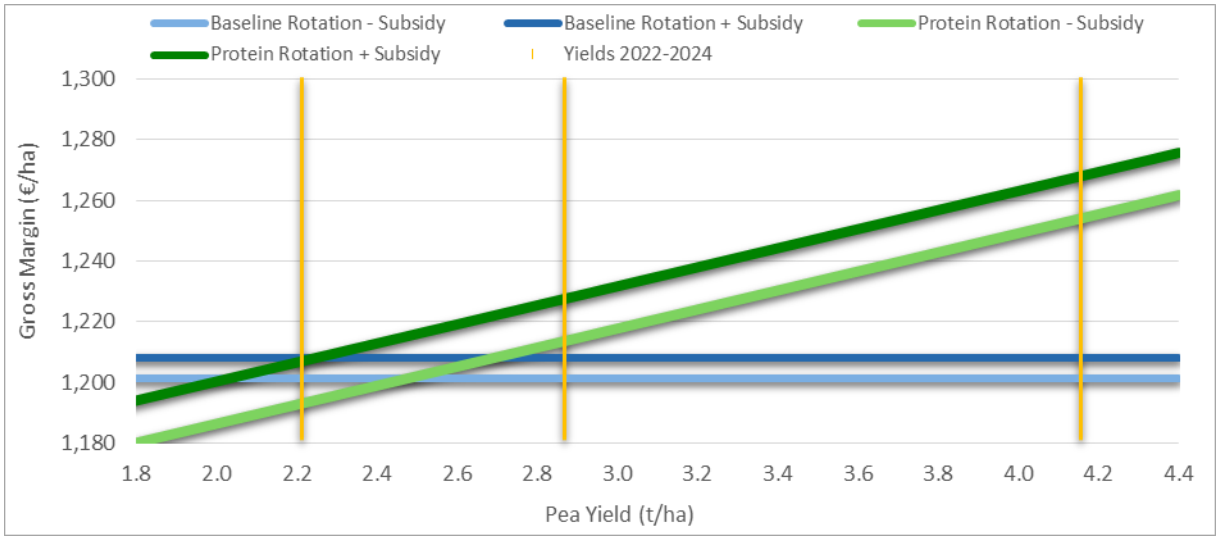


Figure 6: Sensitivity of rotation-level gross margins to changes in pea yield.
Source: *agri benchmark* calculations.

Overall, the results indicate that the competitiveness of peas depends strongly on yield performance. While crop rotation effects and support payments improve economic outcomes, profitability remains sensitive to variations in yields. However, the economic performance of peas partly depends on the high price levels and crop rotation effects assumed in the assessment, both of which may vary under different market and production conditions.

3.4.4. Additional Considerations for the Economic Viability

The expert discussion provides important insights beyond the quantitative economic analysis and helps explain the economic performance of pea cultivation in Funen (see Protocol A-3). Overall, the discussion confirms the relevance of crop rotation effects identified in the economic analysis, while highlighting several agronomic, market-related, and regulatory challenges that may limit the economic attractiveness of pea production under practical farming conditions.

A major advantage of pea cultivation is its positive crop rotation effect. The expert reports substantial yield increases in winter wheat following peas, combined with reduced nitrogen fertilizer requirements in the subsequent winter wheat. In addition, peas contribute to crop diversification and provide an alternative crop in cereal-dominated rotations. Peas are considered an excellent preceding crop for winter wheat. Their positive effects on soil structure allow plowing before winter wheat to be replaced by harrowing, thereby reducing labor requirements, fuel consumption, and machinery operating costs. Peas can be integrated into existing crop rotations without substantially affecting labor peaks during seeding or harvest. However, the expert assessment suggests that the magnitude of these benefits may vary between farms depending on local soil, weather, and management conditions. Consequently, the assumed crop rotation effect should be interpreted as a representative estimate rather than a universally achievable outcome.

The discussion also confirms several production risks that are reflected in the yield and sensitivity analyses. Peas possess a shallow root system and are particularly vulnerable to drought during flowering and grain filling. As a result, yield performance is highly dependent on annual weather conditions, which contributes to the comparatively high yield variability observed in the assessment. The expert identifies drought sensitivity as one of the main constraints to stable pea production in Denmark. Additional production challenges arise from limited crop protection options. Disease, pest, and weed management are considered particularly challenging due to the limited availability of

registered crop protection products, with weed control representing the main production constraint. The expert notes that future restrictions on pesticide use may further increase production risks. An agronomic benefit of pea cultivation is the availability of alternative herbicide active substances for the control of Italian ryegrass and blackgrass, thereby expanding weed-management options within the crop rotation. Pea harvesting can be complicated when plants are pulled from the soil together with their roots, introducing soil into the combine harvester and increasing wear. In addition, peas are particularly prone to lodging. As lodged crops must be harvested at a low cutting height, the risk of stones entering the combine harvester and damaging harvesting equipment increases. Furthermore, the integration of a new crop is associated with additional management decisions and practical requirements, such as the need for separate storage capacity. These factors may represent barriers to the adoption of pea cultivation on farms.

Several findings from the expert discussion suggest that the relatively high pea prices observed during the assessment period should be interpreted cautiously. According to the expert, peas in Denmark are predominantly used for animal feed, while only a limited share is marketed for human consumption under specific contracts. Limited market access is identified as a further constraint to the expansion of pea cultivation. Demand for peas remains limited, particularly outside established feed channels. Failure to meet quality standards can result in substantial price penalties or restrict access to certain market channels. Moisture content, cleanliness, seed damage, protein content, and the presence of contaminants influence marketability and final prices. Compliance with quality requirements for human consumption often requires higher expenditures on fungicides and insecticides than production intended for feed use. The expert further emphasizes that peas are not considered a high-value crop within current Danish farming systems and face competition from alternative crops that offer comparable or superior economic returns.

Current support payments are considered less important than market conditions and production performance. While existing support schemes contribute positively to profitability, the expert notes that factors such as low product prices, yield instability, limited pesticide availability, storage requirements, and operational challenges are of greater relevance for farmers' cultivation decisions. Accordingly, higher and more stable market prices are identified as the most important prerequisite for expanding pea cultivation in the region. Additional measures to support pea cultivation include reducing quality-related price and marketing risks, improving yield stability and quality traits through breeding, strengthening technical solutions for weed control and harvesting, and promoting the role of peas in crop rotations as a source of plant protein and crop rotation effects. According to the expert, increasingly stringent nitrogen regulations may limit the future expansion of pea cultivation, as nitrogen residues from pea production are fully included in growers’ nitrogen budgets, thereby reducing the amount of nitrogen fertilizer that can be applied in subsequent crops. This may negatively affect whole-farm profitability and reduce the economic attractiveness of pea cultivation.

Overall, the expert discussion confirms that peas can contribute positively to crop rotations. However, the economic attractiveness of pea cultivation depends strongly on achieving favorable market prices and realizing the assumed crop rotation effects. High yield variability, quality-related price risks, limited market opportunities, and increasing production challenges may reduce profitability under practical farming conditions. Consequently, the economic performance of peas observed in the assessment should be interpreted in the context of both the comparatively high market prices and the substantial crop rotation effects assumed for the analyzed production system. The transferability of the results to other regions should be assessed carefully.

3.5. Faba Bean Cultivation in Leinster, Ireland

3.5.1. Regional Context and Cropping Systems

Faba Bean Cultivation in Ireland

The area cultivated with the crops beans and peas has increased from approximately 3,500 ha in 2014 to an average of 15,300 ha during 2022–2024. Faba beans account for around 95 % of the cultivation area, while peas represent only a minor share. The Southern region and Eastern and Midland region are the main production areas, with approximately 7,500 ha and 7,730 ha, respectively (Central Statistics Office, 2026). Leinster, located in the Eastern and Midland Region, serves as the representative region for the assessment of faba bean cultivation in Ireland owing to its substantial cultivation area and the regional expertise provided by the local project partner.

Regional Conditions in Leinster

Leinster is located in eastern Ireland and is characterized by a mean annual temperature of approximately 10.5 °C and average annual precipitation of around 850 mm (Copernicus Climate Change Service, 2026). The region is well suited to faba bean cultivation due to its fertile, well-drained loam and clay loam soils with good moisture-holding capacity. Moderate temperatures and generally favorable growing conditions support crop establishment, flowering, and grain filling, while adequate soil moisture reduces the risk of drought stress.

Characteristics of Faba Bean Cultivation

Faba bean (*Vicia faba* L.) is a grain legume with a protein content of approximately 29 % (Sinkovič et al., 2023) (see Profile A-4). It is used for animal feed, human consumption, and increasingly for plant-based food products (Stoddard et al., 2022). Faba beans are best suited to fertile soils with good water-holding capacity and perform well under cool and moist growing conditions. Drought stress during flowering and grain filling can negatively affect yield performance (Stoddard et al., 2022; Stoddard & Schauman, 2022). Two cultivation types are commonly distinguished: spring beans and winter beans. Spring beans are the dominant production system in Ireland, while interest in winter beans has increased in recent years due to their potential to better utilize winter soil moisture and avoid periods of summer drought (Murphy et al., 2022).

Crop Rotations in Leinster

The typical crop rotation in Leinster is defined as a six-year rotation consisting of winter barley, winter oilseed rape, winter wheat, malting barley, spring barley, and a second winter wheat. All crops contribute equally to the rotation, each accounting for 17 % of the cultivated area. To integrate faba beans as a protein crop into the cropping system, spring barley is replaced by faba beans in the rotation. Consequently, the protein crop rotation consists of winter barley, winter oilseed rape, winter wheat, malting barley, faba beans, and a second winter wheat, with each crop again representing 17 % of the total rotation area. Malting barley is considered a suitable preceding crop for faba beans because it leaves relatively low levels of residual soil nitrogen. The nitrogen fixed by faba beans can be utilized by the subsequent winter wheat.

3.5.2. Gross Margin Analysis

Yields and Prices

The average faba bean yield during the assessment period amounts to 5.4 t/ha. Across individual years, yields vary between 5.0 and 6.1 t/ha, representing 92–112 % of the three-year average (see Table A-4). Winter barley exhibits even lower yield variability (94–103 %), while winter wheat and

winter oilseed rape show a similar range compared to faba beans (89–110 %). Slightly higher variability is observed for malting barley and spring barley (89–113 %). Overall, all assessed crops exhibit relatively stable yield levels, indicating a comparatively low production risk associated with annual yield fluctuations. In this context, the combination of high absolute yields and comparatively low yield variability makes faba bean production in Leinster particularly noteworthy.

In contrast, price variability exceeds yield variability for faba beans. The average faba bean price amounts to 293 €/t and ranges from 250 to 347 €/t, corresponding to 85–118 % of the three-year average price. The observed prices primarily reflect the use of faba beans as livestock feed. Similar to faba beans, the competing crops also exhibit greater variability in prices than in yields. Winter oilseed rape (86–119 %) exhibits a similar level of price variability to faba beans, while price fluctuations are even greater for the remaining crops, ranging from 83 % to 128 % of their respective average prices.

For all assessed crops, price variability exceeds yield variability, indicating that market conditions represent a more important source of economic uncertainty than production performance. Consequently, price fluctuations constitute the dominant economic risk for both faba bean production and the competing crops under the assessed conditions.

Revenues and Costs

The crop rotation effect of faba bean cultivation is derived from two effects in the subsequent winter wheat: a yield increase and reduced nitrogen fertilizer requirements. A yield increase of 1.0 t/ha and nitrogen fertilizer savings of 30 kg N/ha are assumed. Together, these effects result in an average crop rotation effect of 320 €/ha, ranging from 261 to 394 €/ha across the assessed years. The crop rotation effect is dominated by yield increases, which account for 78 % of the total effect, while nitrogen fertilizer savings contribute the remaining 22 %. These results highlight the substantial contribution of faba beans to crop rotation performance.

Faba bean revenues average 2,372 €/ha (2,054–2,810 €/ha) during the assessment period. Faba bean sales account for 67 % of total revenues, supported by the comparatively high yield level achieved by faba beans. Additional revenues originate from crop rotation effects (13 %), while governmental support payments account for the remaining 19 %, averaging 459 €/ha. Support payments for protein crop cultivation consist of CAP payments and additional contribution provided by the Irish government (Department of Agriculture, 2023a). The level of support payments varies between years depending on the available budget and the total cultivation area of protein crops (300–583 €/ha). Among the assessed crops, malting barley (2,479 €/ha) and winter wheat (2,775 €/ha) generate higher average revenues than faba beans. In contrast, revenues from winter oilseed rape (2,287 €/ha), winter barley (2,268 €/ha), and spring barley (1,958 €/ha) remain below those of faba beans. All competing crops receive additional revenues from support payments linked to straw incorporation. The payment supports the incorporation of cereal and oilseed rape straw into the soil to improve soil fertility and increase soil carbon sequestration. Support payments for straw incorporation amount to 250 €/ha for cereals and 150 €/ha for oilseed rape (Department of Agriculture, 2023b).

Faba beans exhibit substantially lower cost variability (92–111 % of the three-year average) than the competing crops (76–122 %). With average direct costs of 545 €/ha (503-605 €/ha), faba beans have the lowest cost level among all assessed crops. Costs are mainly attributable to seeds (37 %), followed by pesticides (35 %) and fertilizers (27 %). Winter wheat records the highest average direct costs at 1,290 €/ha, followed by winter barley (1,215 €/ha), winter oilseed rape (1,064 €/ha), spring barley (905 €/ha), and malting barley (887 €/ha). The high share of fertilizer costs for the competing crops is particularly noteworthy, ranging from 58 % of total direct costs for winter wheat to 69 % for winter

oilseed rape. The fertilizer expenditures are followed by pesticide costs, seed costs, and miscellaneous costs.

Gross Margins at Crop Level

In the scenario including support payments, faba bean cultivation achieves the highest average gross margin among the assessed crops, amounting to 1,827 €/ha (1,550–2,285 €/ha). Malting barley (1,592 €/ha) and winter wheat (1,485 €/ha) rank second and third, respectively, followed by winter oilseed rape (1,224 €/ha), winter barley (1,053 €/ha), and spring barley (1,053 €/ha). Although faba beans do not generate the highest revenues, their comparatively low direct costs result in a clear advantage in gross margins. Consequently, faba beans appear to be highly competitive under the assessed conditions.

Without support payments, the ranking of the crops remains unchanged. Faba beans continue to achieve the highest gross margin (1,368 €/ha, range 1,057–1,985 €/ha), while spring barley remains the least profitable crop (803 €/ha). This result can be explained by the fact that all assessed crops receive support payments, although at different levels. Consequently, support payments influence the magnitude of gross margins but do not fundamentally alter the relative competitiveness of the analyzed crops.

All assessed crops exhibit annual variability in gross margins resulting from fluctuations in yields, market prices, and direct costs. Gross margin variability for faba beans ranges from 85–125 % of the three-year average. In comparison, the competing crops show substantially greater variability, ranging from 41–173 %. Malting barley exhibits the lowest variability among the competing crops (65–156 %), whereas spring barley shows the highest variability (41–173 %). These results indicate that faba bean production is characterized by comparatively stable economic performance. In addition to high and stable yields, crop rotation effects and support payments provide additional sources of revenue that strengthen profitability despite fluctuations in market conditions.

The difference in gross margins between the most profitable competing crop, malting barley, and the least profitable competing crop, spring barley, amounts to approximately 540 €/ha. Despite this considerable difference in profitability, all crops remain part of existing crop rotations.

Gross Margins at Crop Rotation Level

Including support payments, the protein crop rotation achieves an average gross margin of 1,444 €/ha, compared with 1,315 €/ha for the baseline rotation. As a result, the protein crop rotation achieves an average gross margin advantage of 129 €/ha. Excluding support payments reduces the gross margin advantage of the protein crop rotation to 94 €/ha, although the rotation continues to outperform the baseline rotation. Consequently, the integration of faba beans improves crop rotation profitability under both support-payment scenarios.

Across all assessed years, the protein crop rotation consistently generates higher gross margins than the baseline rotation. Under the support-payment scenario, the annual profitability advantage ranges from 77 to 210 €/ha. Even without support payments, the economic benefit remains positive, varying between 51 and 155 €/ha. Thus, the protein crop rotation achieves higher gross margins than the baseline rotation in every assessed year and under both support-payment scenarios.

Support payments have a substantial influence on crop rotation profitability. Without support payments, the average gross margin of the baseline rotation decreases by 233 €/ha, while the gross margin of the protein crop rotation declines by an average of 268 €/ha, with annual reductions ranging

from 242 to 289 €/ha. These results illustrate the importance of support payments for the economic performance of both crop rotation systems.

The strong performance of the protein crop rotation can be explained by two factors. First, faba beans represent the most competitive crop in the assessment. Second, the design of the protein crop rotation contributes to improved profitability. In the protein crop rotation, spring barley, the crop with the lowest gross margin, is replaced by faba beans, the most profitable crop in the assessment. Consequently, the improved profitability of the protein crop rotation reflects both the inclusion of a protein crop and a more economically favorable crop rotation structure.

3.5.3. Parity Prices and Sensitivity Analysis

Parity Price Analysis

The parity price analysis is based on an average faba bean yield of 5.4 t/ha, average direct costs of 545 €/ha, and an average crop rotation effect of 320 €/ha. Regardless of whether support payments are included, faba beans achieve the highest gross margin among the assessed crops. Consequently, parity prices indicate the extent to which faba bean prices could decline while maintaining their economic advantage over the competing crop.

In the scenario including support payments, a parity price of 250 €/t is required to achieve the same gross margin as malting barley, corresponding to a price buffer of 15 % relative to the average observed faba bean price. The lowest observed faba bean price during the assessment period was 250 €/t in 2024, which would still be sufficient to maintain parity with malting barley. These results indicate that faba bean prices could decline substantially before the relative ranking of crop-level gross margins changes.

When support payments are excluded, parity prices increase, reducing the economic buffer between faba beans and malting barley. To maintain parity with malting barley, a faba bean price of 288 €/t is required, corresponding to a potential price reduction of approximately 2 %.

At the crop rotation level, the parity price is identical to that for spring barley, as faba beans replace spring barley in the protein crop rotation. Under the support-payment scenario, a faba bean price of 151 €/t is sufficient to achieve parity with the baseline rotation, corresponding to a possible price decline of 49 %. Without support payments, the parity price increases to 189 €/t, still allowing a price reduction of 36 % while maintaining the profitability of the protein crop rotation.

The relationship between winter wheat and faba bean prices remains relatively stable throughout the assessment period, with annual price ratios ranging from 1:1.10 to 1:1.35 and averaging 1:1.18. This average ratio is slightly below the long-term price relationship of 1:1.20–1.30 commonly reported by experts for protein crops used in animal feed. Nevertheless, the observed values remain broadly consistent with this historical range and suggest a close connection between wheat and faba bean markets. The results indicate that the assessed faba bean prices largely reflect feed-market conditions.

Price Sensitivities

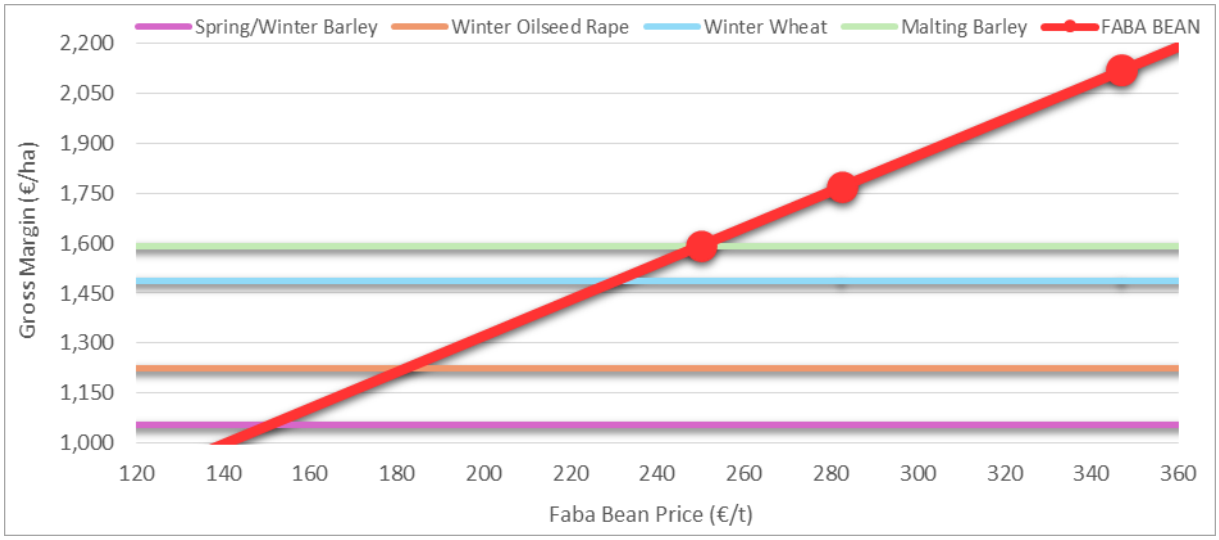


Figure 7: Sensitivity of crop-level gross margins to changes in faba bean price (including support payments).
Source: *agri benchmark* calculations.

The gross margin analysis indicates that price variability represents a greater source of economic risk than yield variability for faba bean production. While yields remain relatively stable, fluctuations in market prices have a substantial influence on profitability. Figure 7 illustrates the relationship between faba bean prices and crop-level gross margins. Even at comparatively low price levels, faba beans remain competitive with most assessed crops. As prices increase, the gross margin advantage of faba beans widens considerably. The implications at the crop rotation level are shown in Figure 8. The protein crop rotation achieves parity with the baseline rotation even at relatively low faba bean price, while higher prices increase its profitability advantage. The figure also highlights the considerable effect of support payments, resulting in a clear separation between the scenarios with and without support payments.

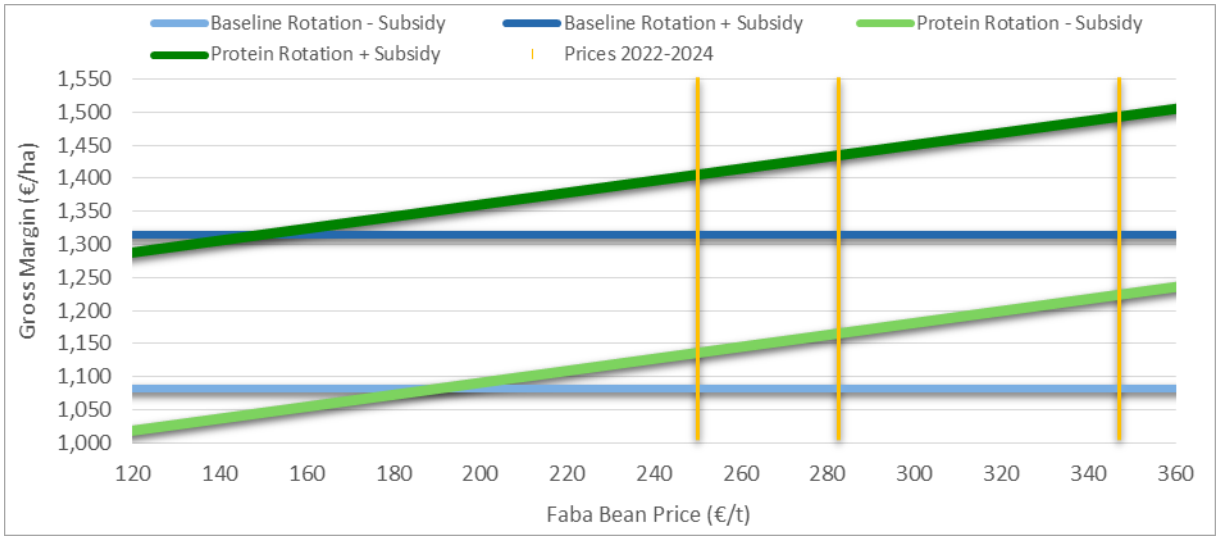


Figure 8: Sensitivity of rotation-level gross margins to changes in faba bean price.
Source: *agri benchmark* calculations.

Overall, the sensitivity analysis confirms that market prices are the primary driver of the economic performance of faba bean cultivation. At the same time, stable yields, positive crop rotation effects, and support payments contribute to the strong competitiveness of faba beans. The performance of

the protein crop rotation is further supported by the replacement of spring barley, the least profitable crop in the baseline rotation. However, the practical implementation of this rotation and the transferability of the results to other production systems should be evaluated carefully, taking local agronomic, market, and regulatory conditions into account.

3.5.4. Additional Considerations for the Economic Viability

The following agronomic and market-related factors influencing the competitiveness of faba bean cultivation in Ireland are identified in the expert discussion. Faba bean is a crop highly suited to Irish pedoclimatic conditions. Its large seed and pod structure require consistent levels of moisture to mature; thus, the heavy, clay-based soils found throughout large parts of Ireland and a climate conducive to high levels of rainfall, provide an ideal environment for faba bean cultivation. As a result, yields of faba bean have been shown to be among the highest achieved globally, potentially reaching 7 t/ha, almost double the yields observed in other European countries such as Germany and France.

Its strong root system and nitrogen-fixing ability are of great benefit to the performance of not only the crop itself but to subsequent crops in a rotation. Following harvest, nitrogen contained in root nodules and crop residues is gradually mineralized by soil microorganisms, making it available for uptake by subsequent crops. This has been shown to increase yields in crops such as winter wheat by approximately 1 t/ha. Its fibrous root system and deep taproot can alleviate compacted soils thereby improving establishment of subsequent crops.

Ireland's large livestock sector offers a steady market demand for feed protein which is mostly met by imported sources. On average imports of high protein feeds such as soybean meal exceed 1.5 million tonnes annually, which highlights the large opportunity to utilize indigenous protein feeds such as faba bean. However, low economic value for the crop means subsidization with governmental support payments is essential to maintain production at levels sufficient for feed merchants to consider their inclusion in rations. This stabilization effect is partially eroded by yield variability from year to year, a factor of inexperience in the best agronomic management practices and adverse climatic conditions. Research has demonstrated that selection of the correct planting date per region can reduce the risk of a farmer achieving low yields.

Although a well-established connection between feed merchants and farmers exists, whereby seed is sold for planting and purchased back by the merchant following harvest, moisture levels of harvested grain often exceed merchant thresholds for storage, resulting in additional costs for pre-treatments such as drying. This variability in both moisture content and yield results in a level of reluctance on the part of feed merchants to invest further in the infrastructure to enable the inclusion of a higher quantity of faba bean feed in their rations. Furthermore, infrastructure required to process the faba bean into more premium food-grade ingredients does not exist in Ireland at present. As a result, the ability to obtain higher value for producers is not possible until innovation occurs in downstream value chains.

3.6. Cross-Comparison of Country-Crop Combinations

The four country-crop combinations illustrate substantial differences in the economic performance of protein crops across regions and production systems. The results demonstrate that the competitiveness of protein crops is influenced by yield performance, market conditions, crop rotation effects, and support payments. At the crop level, faba bean shows the strongest economic performance, combining high and stable yields with substantial crop rotation effects. Lupin is highly dependent on support payments, shifting from the most to the least profitable crop when support

payments are excluded. Pea achieves intermediate profitability, supported by crop rotation effects and favorable market prices. Chickpea consistently outperforms durum wheat but remains less profitable than irrigated spinach, with profitability strongly influenced by yield variability.

At the crop rotation level, faba bean and pea rotations consistently outperform their respective baseline rotations in all assessed scenarios, whereas the profitability advantage of the lupin rotation depends on the inclusion of support payments. Due to the specific conditions of the case study (see below), chickpea cannot be integrated profitably into the assessed crop rotation (Figure 9).

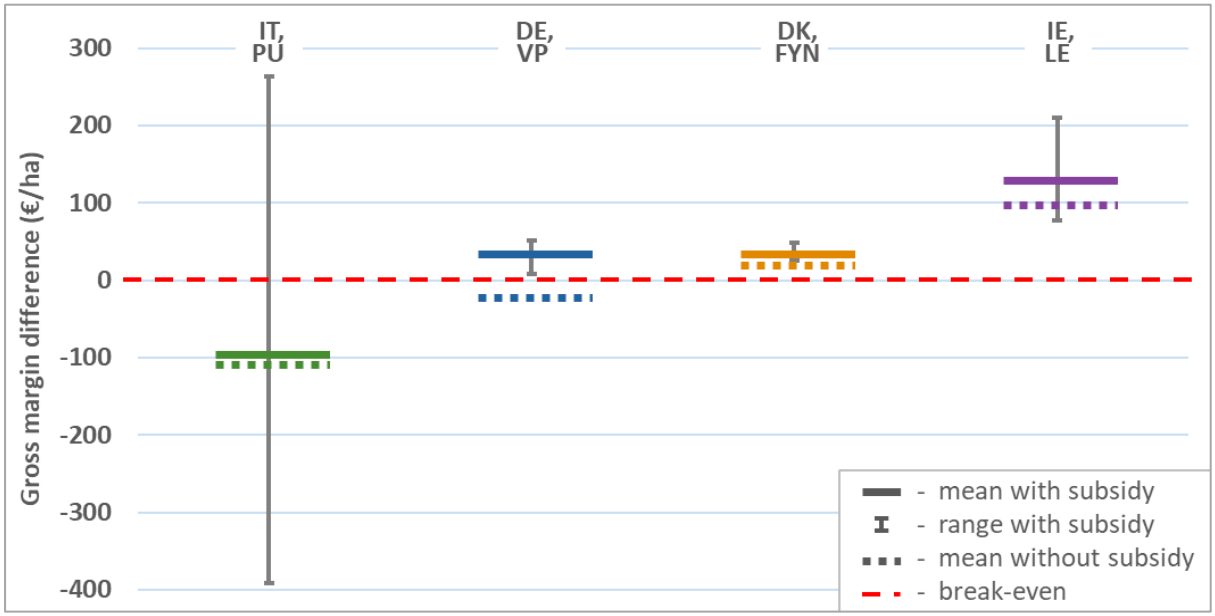


Figure 9: Change in gross margins from introducing protein crops into crop rotations (compared to baseline rotations, average effects and variability, by region).
Source: *agri benchmark* calculations.

Economic performance is strongly influenced by yield and market developments. While faba beans combine high yields with relatively stable production, chickpeas, peas, and lupins exhibit greater yield variability, making yield performance a key source of economic risk (Figure 10). The pronounced interannual yield variation observed across several case studies suggests that longer time series would improve the robustness of assessments and reduce the influence of year-specific effects. Chickpeas achieve the highest market prices and the lowest price variability, reflecting their integration into food markets. Peas also benefit from comparatively high prices, whereas lupins and faba beans exhibit lower and more variable prices due to their predominant use in feed markets. This suggests that integration into food markets will lead to higher prices and may contribute to longer-term supply relationships, potentially reducing price volatility. However, these benefits are often associated with higher quality requirements and more demanding market access conditions.

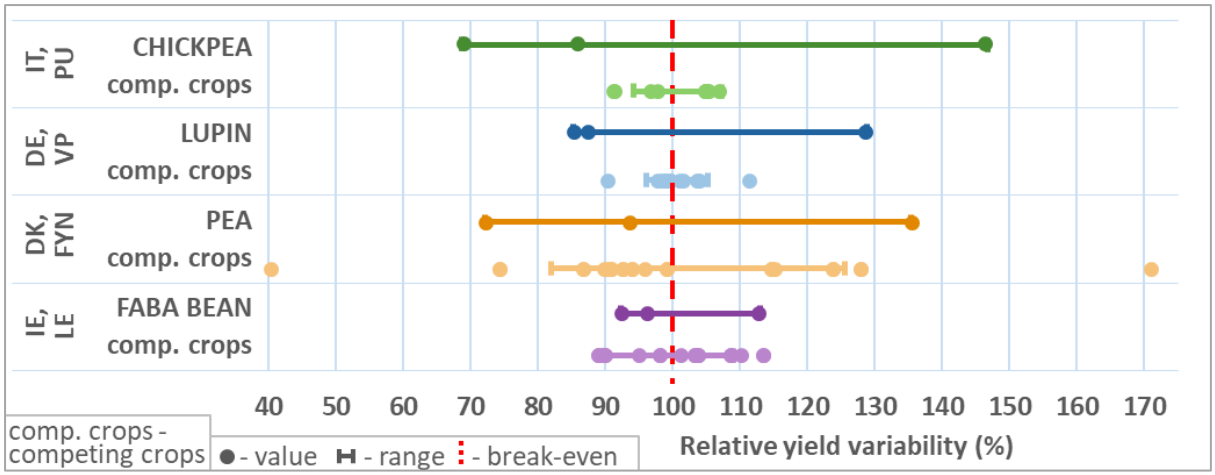


Figure 10: Yield variability of protein crops compared with competing crops (within crop rotations and across regions; mean 2022-2024, range and individual values).
Source: *agri benchmark* calculations.

However, this major advantage of access to human food markets is not reflected in the economic assessment of chickpeas. Due to phytosanitary constraints, chickpeas and spinach, which is an important component of the assessed crop rotation, cannot be grown within the same rotation. Consequently, chickpeas must compete with spinach, which is by far the most profitable crop in the farm. Under production conditions without such a highly competitive alternative crop, the economic performance of chickpeas would be considerably more favorable. For example, if chickpeas were to replace a portion of the durum wheat in the assessed rotation in Apulia, their integration would increase the average crop rotation gross margin by approximately 200 €/ha, making chickpeas the most profitable crop option within the analyzed system.

The highest crop rotation effects are observed for peas, followed by faba beans and lupins. These effects are primarily driven by yield increases in the subsequent crop and are supplemented by nitrogen fertilizer savings and, in the case of lupin cultivation, reduced plant protection costs within the crop rotation. The results suggest that crop rotation effects can be substantial, although their magnitude varies considerably between the case studies. In addition, experts indicate that these benefits may become even more important under certain conditions, particularly in response to increasing weed management challenges in winter crop-dominated systems. Therefore, further research and resources should be devoted to improving the understanding and quantification of crop rotation effects under different agronomic and regulatory conditions, including varying levels of pest and weed pressure and the availability of crop protection products.

The importance of support payments varies considerably between case studies. While they contribute only marginally to the profitability of chickpeas and peas, they play a decisive role in the competitiveness of lupins and faba beans. These findings highlight the importance of policy design and regional support schemes for the economic viability of protein crops.

The focus group discussions largely confirm the quantitative results and identify market access, quality requirements, and yield instability as the main constraints, while crop rotation effects and diversification are considered key advantages.

Overall, the comparison demonstrates that the competitiveness of protein crops is determined by a combination of market conditions, yield stability, crop rotation effects, and policy support. No single factor alone explains profitability across all case studies. Instead, the relative importance of these drivers differs considerably between crops and regions. The results therefore highlight the importance

of site-specific assessments. Particular caution is required when transferring the results between regions, as key determinants of profitability differ substantially among the assessed production systems.

4. Conclusion

Considering the political goal to expand the European protein crop production, the analysis of the four case studies leads to the following conclusions:

1. Given that farmers typically accept considerable variation in the gross margins of individual crops within their crop rotations, the competitiveness of protein crops should be assessed relative to the most relevant alternative crop(s) and the overall crop rotation. Applying this approach indicates that faba beans in Ireland are economically competitive, whereas the competitiveness of peas in Denmark, lupins in Germany, and chickpeas in Italy is more limited or, in the latter case, not achieved within the assessed crop rotation. These findings are primarily attributable to comparatively low yield levels and/or unfavorable market conditions and generally could not be compensated for by lower production costs, crop rotation effects, or support payments.

2. Furthermore, protein crops generally exhibit greater yield variability than competing crops, making production risk a key constraint to their economic competitiveness. The underlying causes are not yet fully understood, but several factors are likely to contribute. As predominantly spring-sown crops, protein crops are often more exposed to adverse weather conditions during establishment and are characterized by relatively slow early growth and long establishment phases. In addition, crop-specific traits, such as soft stems and low pod insertion, may increase production and harvesting risks. In principle, these constraints could be addressed through plant breeding. However, the comparatively small seed market for many protein crops reduces the economic incentives for substantial private-sector investment in complex and costly breeding programs. Moreover, many of the traits associated with yield stability are genetically complex, implying that breeding progress is likely to require considerable time. Consequently, major improvements in yield stability through breeding should not be expected in the short to medium term. Current production risks therefore have to be regarded as an inherent characteristic of protein crop production and are likely to require price premiums or other economic incentives to compensate growers for the additional risk associated with their cultivation.

3. There are cases in which premium prices can be achieved when protein crops, or a share of the production, meet the quality requirements of human food markets and are marketed accordingly. The Italian chickpea case study provides a prominent example. Compared to durum wheat, a key component of regional arable crop rotations, chickpeas generate a gross margin that is approximately 620 €/ha higher. Under these conditions, chickpea cultivation is economically very competitive with durum wheat without requiring additional policy support.

4. Therefore, improved marketing structures and better access to food markets appear to be among the most important drivers for enhancing the on-farm competitiveness of protein crops. However, a major challenge arises from the fact that food processors can source protein crops from global markets. In particular, countries such as Canada and Australia are well positioned to produce large quantities of protein crops at comparatively low production costs and with a high degree of product standardization. As a result, imports have increased substantially in recent years. Against this background, further efforts should be directed towards (a) improving the understanding of sourcing strategies and procurement decisions of food-processing companies and, based on these

insights, (b) identifying barriers and developing appropriate incentives to encourage the sourcing of European-grown protein crops.

5. Crop protection in protein crops is identified as a major challenge across all case studies. While the number of available crop protection products is declining for arable crops in general, this trend is particularly pronounced for minor crops such as protein crops. In addition to increasingly stringent regulatory requirements, the relatively high costs associated with obtaining authorization for crop protection products in comparatively small markets reduce incentives for agrochemical companies to pursue registrations for these crops. Consequently, policymakers should carefully evaluate whether existing regulatory frameworks could be adapted to strengthen incentives for product registration in protein crops while avoiding further regulatory changes that may exacerbate the current limitations in available crop protection options.

6. In the German case study, relatively high support payments (600 €/ha) play a decisive role in enabling lupins to achieve economic competitiveness. This raises the question of whether allocating substantial public resources to achieve a comparatively small increase in protein crop production represents an efficient policy approach.

7. While the crop rotation effects of protein crops are not sufficient on their own to fundamentally alter the economic performance of the assessed rotations, they can nevertheless be economically significant. For example, in the German lupin case study, crop rotation effects amount to approximately 155 €/ha, compared to market revenues from lupin production of around 1,100 €/ha.
   Furthermore, winter crop-dominated rotations are particularly susceptible to the development of herbicide-resistant weed populations, and protein crops provide valuable opportunities to diversify weed management strategies within such systems. As weed management challenges, particularly those associated with grass weeds in winter crop-based rotations, are expected to intensify in the future, the value of these crop rotation effects is likely to increase. Therefore, greater emphasis should be placed on the systematic assessment, monitoring, and communication of crop rotation effects within both research and advisory activities.

Publication Bibliography

Alpmann, D., & Schäfer, B. C. (2014). Der Wert von Körnerleguminosen im Betriebssystem. Report. UFOP-Praxisinformation. Fachhochschule Südwestfalen. https://www.ufop.de/files/9013/9593/2050/RZ_UFOP_1157_Praxis_Koernerleguminosen_web.pdf. Accessed 03/07/2026.

Bundesministerium für Landwirtschaft, Ernährung und Heimat. (BMLEH). (2026). Öko-Regelungen. Webpage. https://www.bmleh.de/DE/themen/landwirtschaft/eu-agrarpolitik-und-foerderung/direktzahlung/oeko-regelungen.html. Accessed 02/07/2026.

Central Statistics Office. (2026). Area Farmed in June (AQA06). Statistical database. https://data.cso.ie/. Accessed 02/07/2026.

Copernicus Climate Change Service, Climate Service Store. (2026). E-OBS daily gridded meteorological data for Europe from 1950 to present derived from in-situ observations. Dataset. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). https://doi.org/10.24381/cds.151d3ec6. Accessed 02/07/2026.

Danish Agricultural Agency. (2026). Varieret planteproduktion. Webpage. https://lbst.dk/tilskud/tilskudsguide/2023-og-senere/varieret-planteproduktion. Accessed 02/07/2026.

De Santis, M. A., Rinaldi, M., Menga, V., Codianni, P., Giuzio, L., Fares, C., & Flagella, Z. (2021). Influence of organic and conventional farming on grain yield and protein composition of chickpea genotypes. *Agronomy*, 11(2). https://doi.org/10.3390/agronomy11020191.

Department of Agriculture, Food and the Marine. (2023a). Protein Aid Scheme. Webpage. https://www.gov.ie/en/department-of-agriculture-food-and-the-marine/services/protein-aid-scheme/. Accessed 02/07/2026.

Department of Agriculture, Food and the Marine. (2023b). Straw Incorporation Measure (SIM). Webpage. https://www.gov.ie/en/department-of-agriculture-food-and-the-marine/services/straw-incorporation-measure-sim/. Accessed 02/07/2026.

Deutsche Saatveredelung AG (DSV). (2022). Die Weiße Lupine (*Lupinus albus*) Anbauratgeber. Report. Lippstadt. https://www.dsv-saaten.de/DE/Downloads/weisse-lupine/DSV_148b210_LupinenAnbauberater_080322.pdf. Accessed 03/07/2026.

Donna, M., Pigna, G., Scapino, M., Colombatto, P., Varetto, P., & Blandino, M. (2025). Pesticide application management for the cultivation of soybean and chickpea for food supply chains with zero-residues. *Journal of Agriculture and Food Research*, 19. https://doi.org/10.1016/j.jafr.2024.101567.

Eurostat. (2026). Crop production in EU standard humidity. Statistical database. https://doi.org/10.2908/APRO_CPSH1. Accessed 02/07/2026.

Gesellschaft zur Förderung der Lupine e. V. (GFL). (2025). Lupinen – Anbau und Verwertung. Report. Bocksee. 7. Auflage. https://lupinenverein.de/wp-content/uploads/2025/08/2025_GFL_Broschuere_online_komprimiert.pdf. Accessed 03/07/2026.

Istat. (2026). Areas and production - overall data. Statistical database. https://esploradati.istat.it/databrowser/#/en/dw/categories/IT1,Z1000AGR,1.0/AGR_CRP/DCSP_COLTIVAZIONI/IT1,101_1015_DF_DCSP_COLTIVAZIONI_1,1.0. Accessed 02/07/2026.

Kousta, A., Katsis, C., Tsekoura, A., & Chachalis, D. (2024). Effectiveness and Selectivity of Pre- and Post-Emergence Herbicides for Weed Control in Grain Legumes. *Plants*, 13(2). https://doi.org/10.3390/plants13020211.

Macák, M., Candráková, E., Đalović, I., Prasad, P. V. V., Farooq, M., Korczyk-Szabó, J., Kováčik, P., & Šimanský, V. (2020). The influence of different fertilization strategies on the grain yield of field peas (*Pisum sativum* L.) under conventional and conservation tillage. *Agronomy*, 10(11). https://doi.org/10.3390/agronomy10111728.

Ministry of Agriculture, of Food Sovereignty and Forests. (2026). Sostegno accoppiato al reddito per superficie, Colture proteiche Leguminose eccetto soia - PD 06 CIS(09). Webpage. https://www.masaf.gov.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/18889. Accessed 02/07/2026.

Murphy, L. C., Sparkes, D. L., Spink, J. H., & Alves, S. (2022). Yield response of field beans (*Vicia faba*) to plant population and sowing date in a temperate climate. *Irish Journal of Agricultural and Food Research*, 61(2). https://doi.org/10.15212/ijafr-2022-0024.

Notz, I., & Reckling, M. (2022). Utilising the pre-crop effect of grain legumes. Leibniz Centre for Agricultural Landscape Research (ZALF). *Legumes Translated Practice Note 77*.

Palmero, F., Fernandez, J. A., Garcia, F. O., Haro, R. J., Prasad, P. V. V., Salvagiotti, F., & Ciampitti, I. A. (2022). A quantitative review into the contributions of biological nitrogen fixation to agricultural systems by grain legumes. *European Journal of Agronomy*, 136. https://doi.org/10.1016/j.eja.2022.126514.

Preissel, S., Reckling, M., Schläfke, N., & Zander, P. (2015). Magnitude and farm-economic value of grain legume pre-crop benefits in Europe: A review. *Field Crops Research*, 175, 64–79. https://doi.org/10.1016/j.fcr.2015.01.012.

Reckling, M., Bergkvist, G., Watson, C. A., Stoddard, F. L., Zander, P. M., Walker, R. L., Pristeri, A., Toncea, I., & Bachinger, J. (2016). Trade-offs between economic and environmental impacts of introducing legumes into cropping systems. *Frontiers in Plant Science*, 7. https://doi.org/10.3389/fpls.2016.00669.

Rete Rurale Nazionale. (2026). CIS(32) - Sostegno accoppiato al reddito. Report. https://www.reterurale.it/flex/cm/pages/ServeAttachment.php/L/IT/D/a%252Fa%252Fa%252FD.f9f115f3a1387e88f28f/P/BLOB%3AID%3D24602/E/pdf. Accessed 02/07/2026.

Rühl, G., Bramm, A., & Greef, J. (2009). Aspekte des Anbaus von Körnerleguminosen. *Journal Für Kulturpflanzen*, 61(9), 312–317.

Sellami, M. H., Lavini, A., & Pulvento, C. (2021). Phenotypic and quality traits of chickpea genotypes under rainfed conditions in south Italy. *Agronomy*, 11(5). https://doi.org/10.3390/agronomy11050962.

Sinkovič, L., Pipan, B., Šibul, F., Nemeš, I., Tepić Horecki, A., & Meglič, V. (2023). Nutrients, Phytic Acid and Bioactive Compounds in Marketable Pulses. *Plants*, 12(1). https://doi.org/10.3390/plants12010170.

Statistics Denmark. (2026). Harvest by unit, crop, region and time (table HST77). Statistical database. https://www.statbank.dk/statbank5a/default.asp?w=1920. Accessed 02/07/2026.

Statistisches Bundesamt (Destatis). (2026a). Area under cultivation, harvested quantity, yield per hectare (field crops and grassland): Germany, years, types of crops (Code: 41241-0005). Statistical database. https://genesis.destatis.de/datenbank/online/statistic/41241/table/41241-0005/table-toolbar. Accessed 02/07/2026.

Statistisches Bundesamt (Destatis). (2026b). Area under cultivation, harvested quantity, yield per hectare (field crops and grassland): Länder, years, types of crops (Code: 41241-0010). Statistical database. https://genesis.destatis.de/datenbank/online/statistic/41241/table/41241-0010/table-toolbar. Accessed 02/07/2026.

Stoddard, F., Lindström, K., & Schauman, C. (2022). Growing faba bean and pea in the Nordic region. University of Helsinki. *Legumes Translated Practice Note 76*.

Stoddard, F., & Schauman, C. (2022). There is a grain legume for every field. University of Helsinki. *Legumes Translated Practice Note 66*.

Watson, C. A., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C. F. E., Vanhatalo, A., Zander, P., Murphy-Bokern, D., & Stoddard, F. L. (2017). Grain Legume Production and Use in European Agricultural Systems. *Advances in Agronomy*, *144*, 235–303. https://doi.org/10.1016/bs.agron.2017.03.003.

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Profile A-1: Chickpea Cultivation (*Cicer arietinum* L.)

General Characteristics and Appearance



- Grain legume with an erect to semi-erect growth habit and a deep rooting system contributing to drought tolerance.
- Protein content of approximately 19 % and a favorable amino acid profile.
- Primarily produced for human consumption, including dry grain, canned products, and flour.
- Kabuli type is the dominant type in Italy, which is characterized by large, light-colored seeds.

Soil and Climatic Conditions

- Well adapted to Mediterranean climates and performs best under warm and relatively dry growing conditions.
- Naturally drought tolerant but sensitive to waterlogging and prolonged soil moisture.
- Frost can negatively affect crop establishment and yield.
- Well-drained, light soils with low-fertility soils are preferred, while poorly drained sites should be avoided.

Crop Rotation

- Multi-year crop rotation breaks are recommended to minimize the risk of soil-borne diseases.
- Cereals, particularly durum wheat, are suitable preceding crops.
- Winter cereals are suitable subsequent crops and can benefit from residual nitrogen.
- Yield and nitrogen benefits in subsequent crops may be less pronounced in practice than often reported.

Tillage and Sowing

- Deep soil loosening followed by a fine seedbed preparation is recommended prior to sowing.
- Sowing generally takes place from winter to early spring, depending on regional climatic conditions.
- Recommended plant density is approximately 40–50 plants/m².
- Typical sowing depth ranges from 3–5 cm.

Fertilization

- Chickpeas are generally able to satisfy most of their nitrogen demand through biological nitrogen fixation.
- 20–30 kg/ha phosphorus and 20–30 kg/ha potassium are recommended.
- Magnesium and micronutrient applications should be based on soil testing.

Plant Protection

- Chickpeas show limited competitiveness against weeds during the early growth stages.
- Chemical weed, disease, and pest control options are comparatively limited.
- Mechanical weed control is not widely established.

Harvest

- Harvest generally takes place between July and August.
- Careful combine settings are required to minimize seed damage and maintain product quality.
- Market quality is determined by moisture content, grain size, and visual appearance.

Table A-1: Gross margins (GM) of assessed crops and crop rotations in Apulia, Italy (average 2022–2024 and range).
Source: *agri benchmark* calculations.

		Durum Wheat 1	Durum Wheat 2	Spinach	CHICKPEA
Revenue	**€/ha**	**1072** ***(945 - 1188)***	**975** ***(862 - 1079)***	**2525** ***(2097 - 2980)***	**1805** ***(1190 - 2860)***
Yield	t/ha	2.4 *(2.2 - 2.5)*	2.1 *(1.9 - 2.2)*	14.9 *(14.4 - 15.9)*	2.2 *(1.5 - 3.3)*
Price	€/t	399 *(329 - 494)*	399 *(329 - 494)*	169 *(144 - 207)*	786 *(747 - 860)*
Revenue By-product	€/ha	28 *(26 - 30)*	26 *(23 - 27)*	-	-
Support Payment	€/ha	100	100	-	40
Direct Cost	**€/ha**	**483** ***(455 - 510)***	**553** ***(519 - 586)***	**1102** ***(1014 - 1196)***	**675** ***(647 - 692)***
Seed	€/ha	174 *(162 - 180)*	174 *(162 - 180)*	135 *(126 - 140)*	379 *(353 - 392)*
Fertilizer	€/ha	141 *(105 - 185)*	210 *(168 - 261)*	515 *(410 - 639)*	58 *(52 - 63)*
Pesticide	€/ha	159 *(153 - 162)*	159 *(153 - 162)*	432 *(410 - 445)*	228 *(221 - 232)*
Miscellaneous	€/ha	9 *(8 - 9)*	10 *(9 - 10)*	20 *(19 - 21)*	11 *(11 - 11)*
Gross Margin	**€/ha**	**589** ***(490 - 679)***	**423** ***(343 - 494)***	**1423** ***(901 - 1967)***	**1129** ***(543 - 2168)***

Acreage	%	33	33	33	-
GM Baseline Rotation	**€/ha**	**812** ***(691 - 933)***			

Acreage	%	33	33	-	33
GM Protein Rotation	**€/ha**	**714** ***(542 - 1046)***			

Protocol A-1: Focus Group Discussion in Apulia, Italy

The focus group was conducted in December during an in-person meeting with two farmers and one agricultural advisor.

Introduction

1. **For what reason are chickpeas grown on your farm?**
   - To integrate a legume into the durum wheat based crop rotation.
   - To improve soil nitrogen supply.
   - To support crop rotation diversity and soil fertility.

2. **Are the chickpeas used as feed, human nutrition or for seed production? Is the use for your own farm or is the raw material sold?**
   - Chickpeas are mainly produced for human consumption.
   - By-products or non-marketable grains may be used as animal feed.
   - Most of the production is marketed and sold.

Crop Rotation

3. **How long are the cultivation breaks between chickpeas and chickpeas, and between chickpeas and other legumes on your farm?**
   - Chickpeas are typically grown with several years between successive chickpea crops.
   - Winter wheat and other crops are commonly included between grain legumes.

4. **Do you grow cover crops that contain legumes?**
   - Legume-based cover crops are sometimes grown to meet policy requirements or support nematode management.
   - Where land or water resources are limited, marketable cash crops are often preferred.

5. **After which crops do you grow chickpeas and which crop usually follows chickpeas?**
   - Chickpeas are commonly grown after winter wheat.
   - They are followed by various cash crops, including cereals and vegetables.
   - Main crop rotations are durum wheat – durum wheat – chickpeas or beans or spinach or tomato.

6. **Do you have experience with intercropping of chickpeas?**
   - No practical experience with chickpea intercropping has been reported.

7. **How do you assess the crop rotation effect of chickpeas?**
   - The crop rotation effect of chickpeas is generally considered positive.
   - Subsequent crops after chickpeas may benefit from positive agronomic effects, including higher yields, lower nitrogen fertilizer requirements, reduced weed pressure and crop diversification.
   - However, these benefits are often less pronounced in practice than theoretical expectations would suggest, and no concrete values are available for inclusion in the economic analysis.
   - In practice, crop rotation requirements and policy incentives are often more influential.

Tillage and Seeding

8. **Can you implement these seeding recommendations on your farm, or have you had other experiences in practice?**
   - The recommended sowing practices are generally feasible.
   - The recommendations are largely consistent with current farming practice.

9. **Do any problems arise during the seeding of chickpeas?**
   - Sowing is generally considered straightforward.
   - The operations are similar to those used for other arable crops.
   - Rainfall after sowing is regarded as beneficial.

10. **Is sufficient chickpea seed available?**
    - Seed is generally available through standard suppliers without major difficulties.

Fertilization

11. **Would you agree with these fertilizer recommendations or do you follow a different fertilization strategy on your farm?**
    - The recommendations are generally considered appropriate.
    - Fertilization strategies are often kept simple.
    - Phosphorus fertilizer application before or at sowing is recommended, with a second application potentially being applied during the middle of the vegetative growth phase.

Plant Protection

12. **How do you assess these plant protection recommendations? What experiences have you had in practice?**
    - Herbicide applications are considered an important part of chickpea production.
    - Both pre- and post-emergence herbicide applications are regarded as effective.
    - Fungicides may be used, especially under humid conditions.

13. **How do you assess the success of chemical plant protection treatments?**
    - Chemical crop protection is generally considered effective.
    - Success depends on proper timing and application.
    - Occasional challenges with diseases and nematodes under certain conditions have been reported.

14. **Do you have experience with mechanical weed control in chickpeas (harrow, hoe)?**
    - Limited or no practical experience was reported.
    - Mechanical weed control is mainly used in organic farming.

Harvest

15. **Have you had similar experiences regarding the harvesting of chickpeas?**
    - Harvest experiences generally correspond to the described recommendations and observations.

16. **Are there particular challenges in harvesting chickpeas?**
    - Harvesting is generally considered manageable.
    - Maintaining an appropriate grain moisture content (12–14 %) is important.

17. **Do you dry or clean the chickpeas on your farm? Do you use other methods to improve storage stability?**
    - Chickpeas are often marketed directly after harvest.
    - Cleaning, drying, and packaging are frequently carried out by processors, cooperatives, or buyers.

18. **What yields have you harvested in the last six years?**
    - Average yields are approximately 1.5–2.5 t/ha.
    - Yield variability is a major concern.

Marketing

19. **Are there quality requirements in marketing? Can you meet these requirements?**
    - Moisture content is a key quality requirement (12–14 %).
    - Depending on the market channel, grain size and visual quality may also be important.
    - The requirements can generally be met.

20. **Are there governmental support payments for the cultivation of chickpeas? What conditions must be fulfilled?**
    - Governmental support payments of around 40 €/ha are available.
    - Eligibility requires the cultivation of a legume crop and adherence to good agronomic practices.

21. **Does the amount of governmental support payments play a role in your cultivation decision?**
    - Crop rotation considerations and profitability are the main decision factors.
    - Support payments are seen as an additional benefit rather than the primary motivation.

Analysis of the Protein Crop Rotation in the Region (with Chickpeas)

22. **How would your crop rotation change if you integrated chickpeas into your crop rotation?**
    - Chickpeas are mainly integrated for positive crop rotation effects.
    - Economic attractiveness depends strongly on market prices.
    - Gross margins can be similar to or higher than those of competing crops, depending on the year.

23. **Discussion of the gross margin calculation for the protein crop rotation in detail**
    - Profitability is highly influenced by market price developments.
    - In years with favorable prices, chickpeas may achieve higher gross margins than cereals.
    - Positive effects on subsequent crops are generally expected.

24. **How would you integrate the discussed effects of chickpeas on the subsequent crops into this calculation (impacts on yield, quality, N fertilization, crop protection, tillage)?**
    - The crop rotation effect of chickpeas should be considered as described under Question 7.

25. **Considering all operational effects associated with the cultivation of chickpeas, how do you assess the cultivation of chickpeas on your farm?**
    - Chickpea cultivation is viewed positively overall.
    - The crop can be integrated well into existing farming systems.
    - Its attractiveness partly depends on site conditions and irrigation availability, where irrigation is available, chickpeas are often replaced by crops with greater economic returns.
26. **How do you evaluate the further development of chickpea cultivation on your farm?**
    - Farmers generally intend to continue growing chickpeas.
    - Future development depends on profitability, sustainability, and crop rotation requirements.

Profile A-2: White Lupin Cultivation (*Lupinus albus*)

General Characteristics and Appearance



- Grain legume with an upright growth habit, palmately compound leaves, and a deep taproot system.
- High protein content of approximately 38 %, making it one of the highest-protein grain legumes after soybean.
- Used for animal feed, human consumption (increasing demand), and seed production.
- Seed quality may be affected by elevated alkaloid contents and allergenic compounds.

Soil and Climatic Conditions

- Adapted to temperate climates and performs best under moderate temperatures and adequate moisture during flowering.
- Well suited to light to medium-textured soils with good drainage and pH between 5.5–7.3.
- White lupin should generally be grown on sites exceeding 30 soil quality points.
- Waterlogged, compacted, and shallow soils should be avoided.

Crop Rotation

- Minimum break of five years between lupin crops; breaks of two to four years to other legumes.
- Best grown after crops with low residual soil nitrogen levels.
- Winter crops or cover crops are suitable subsequent crops to make use of residual nitrogen.
- Positive crop rotation effects include yield gains and nitrogen fertilizer savings in subsequent crops, reduced pesticide costs in the crop rotation, and further agronomic benefits.

Tillage and Sowing

- Deep tillage in autumn and shallow seedbed preparation in spring are recommended.
- Sowing is typically carried out at soil temperatures above 8 °C from mid-March to late April.
- Recommended seed rate for white lupin: 50–70 seeds/m², seed depth: 2–4 cm.
- Seed inoculation with rhizobia should be considered where lupins have not been grown for more than 8–10 years.

Fertilization

- Nitrogen fertilization is often not required due to the crop's ability to fix atmospheric nitrogen.
- 10–15 kg/ha phosphorus, 40–80 kg/ha potassium, 20–30 kg/ha sulfur, 10–20 kg/ha magnesium.
- Micronutrients such as boron, molybdenum, cobalt, and manganese may be required where deficiencies occur.

Plant Protection

- Lupins generally show limited competitiveness against weeds during the early growth stages due to their relatively slow early development.
- Broadleaf weed control relies mainly on pre-emergence herbicides.
- Limited chemical control options are available for major diseases and pests.
- Mechanical weed control can be achieved through harrowing and hoeing.

Harvest

- Harvest period from mid-August to mid-September.
- Gentle threshing is required to minimize seed damage and maintain quality.

Table A-2: Gross margins (GM) of assessed crops and crop rotations in Western Pomerania, Germany (average 2022–2024 and range).
Source: *agri benchmark* calculations.

		Winter Barley	Winter Oilseed Rape	Winter Wheat	Corn Silage	LUPIN
Revenue	**€/ha**	**1628** ***(1329 - 2044)***	**1944** ***(1595 - 2374)***	**1872** ***(1688 - 2213)***	**1377** ***(1341 - 1450)***	**1853** ***(1639 - 1931)***
Yield	t/ha	7.8 *(7.6 - 8.1)*	3.6 *(3.2 - 4.0)*	7.5 *(7.4 - 7.7)*	39.0 *(38.3 - 39.4)*	3.5 *(2.9 - 4.4)*
Price	€/t	208 *(171 - 252)*	541 *(494 - 595)*	250 *(228 - 286)*	35 *(34 - 37)*	317 *(270 - 381)*
Support Payment	€/ha	-	-	-	-	600
Crop Rotation Effect	€/ha	-	-	-	-	155 *(133 - 174)*
Direct Cost	**€/ha**	**545** ***(459 - 689)***	**663** ***(557 - 818)***	**599** ***(491 - 773)***	**419** ***(370 - 470)***	**359** ***(319 - 429)***
Seed	€/ha	78 *(68 - 84)*	88 *(85 - 92)*	88 *(74 - 97)*	149 *(141 - 158)*	200 *(188 - 206)*
Fertilizer	€/ha	312 *(214 - 447)*	360 *(284 - 497)*	354 *(262 - 524)*	180 *(148 - 222)*	76 *(33 - 149)*
Pesticide	€/ha	152 *(138 - 161)*	210 *(174 - 237)*	156 *(139 - 177)*	63 *(59 - 67)*	82 *(74 - 90)*
Miscellaneous	€/ha	2 *(0 - 4)*	5 *(0 - 10)*	1 *(1)*	27 *(15 - 39)*	1 *(0 - 4)*
Gross Margin	**€/ha**	**1083** ***(838 - 1558)***	**1281** ***(981 - 1817)***	**1274** ***(956 - 1722)***	**958** ***(924 - 980)***	**1494** ***(1320 - 1594)***

Acreage	%	25	25	25	25	-
GM Baseline Rotation	**€/ha**	**1149** ***(965 - 1517)***				

Acreage	%	23	23	23	23	10
GM Protein Rotation	**€/ha**	**1184** ***(1000 - 1525)***				

Protocol A-2: Focus Group Discussion in Western Pomerania, Germany

Four agricultural farms and one seed company participated in the focus group discussion held on March 18, 2026, in Dummerstorf, Western Pomerania. Three farms have long-term experience growing lupins, one of which is managed organically. The fourth farm is introducing lupins into its crop rotation this year.

Introduction

1. **For what reason are lupins grown on your farm?**
   - Source of protein for animal feed (soybean substitute).
   - Reduced purchases of protein feed through on-farm utilization.
   - GMO-free feeding increases the milk price by 1 cent/liter of milk.
   - Component of support schemes promoting diversified crop rotations.
   - Benefits for crop rotation and soil structure.

2. **Do you grow narrow-leafed or white lupins on your farm?**
   - White lupins.
   - Narrow-leafed lupins were grown previously, but low yield levels were problematic.

3. **Are the lupins used as feed, human nutrition or for seed production? Is the use for your own farm or is the raw material sold?**
   - Predominantly used as animal feed on the farm.
   - A portion is sold to agricultural traders.
   - Seed production is an additional use.

4. **If you do not produce lupins for human nutrition: Why is that? Did you have a corresponding offer?**
   - No offers available, as the market is small and marketing is difficult.
   - Problems with the reliability of buyers in the past.
   - Contact with a regional processor has become difficult following a company takeover.

Crop Rotation

5. **How long are the cultivation breaks between lupins and lupins, and between lupins and other legumes on your farm?**
   - A cultivation interval of 5 years is maintained for lupins.
   - No other grain legumes are grown.
   - Cover crop mixtures containing lupins are avoided.

6. **After which crops do you grow lupins and which crop usually follows lupins?**
   - Lupins are grown after corn silage.
   - Winter cereals (winter wheat, winter barley, winter rye) follow lupins.

7. **Do you have experience with intercropping of lupins?**
   - In the past, narrow-leafed lupins and spring rye were grown in a mixture and fed together.
   - Since white lupins mature late (mid-September), suitable mixing crops are lacking.

Crop Rotation Effect

8. **How do you assess the crop rotation effect of lupins?**
   - Yield increases in the following winter crop are possible and depend on the year; increases of up to 1–2 t/ha are possible, with an average increase of 0.5 t/ha in winter barley after lupins compared with winter barley after corn silage.
   - Nitrogen savings in the subsequent crop of approximately 20 kg N/ha.
   - By interrupting cereal rotations, sowing in spring, and using alternative active ingredients, weed pressure is reduced, allowing savings in crop protection measures or the use of cheaper products; this can result in crop protection cost savings of up to 25 €/ha that can be attributed to the crop rotation effect.
   - Positive effects on soil structure; hardpan layers could be partially penetrated.
   - Tillage intensity for seedbed preparation of the subsequent crop can be reduced due to improved soil structure.
   - Spring sowing has no effect on labor peaks, but the late harvest of white lupins is problematic because it coincides with other operations (harvest corn silage, grass mowing, plowing).
   - No effects on the crude protein content of the subsequent crop are observed.
   - No fungicide application can be omitted in the subsequent crop.
   - No effects on the yield of the second subsequent crop are observed.

→ Crop rotation effect of lupins: yield increase in the following crop, savings in N fertilizer in the following crop, and reduced crop protection costs within the rotation.

→ Positive effects on soil structure and reduced tillage after lupins are observed but are difficult to incorporate into farm economic analyses.

Tillage and Seeding

9. **Can you implement these seeding recommendations on your farm, or have you had other experiences in practice?**
   - Sowing recommendations can largely be implemented.
   - Rapid crop emergence is crucial; later sowing under warmer soil conditions is preferred.
   - Inoculation with rhizobial preparations is recommended to secure yields; application with a crop protection sprayer together with herbicide treatments is possible.
   - Sowing should be optimized as much as possible to ensure good crop establishment.
   - Tillage for lupins is implemented according to farm-specific conditions; spring plowing is also possible.
   - Rolling after sowing has shown good results.
   - Wider row spacing should be used when mechanical weed control is practiced (e.g. 50 cm).

10. **Do any problems arise during the seeding of lupins?**
    - Uniform and not excessively deep seed placement is crucial (2–4 cm).
    - An organic mulch layer can impede emergence.

11. **Is sufficient lupin seed available?**
    - Generally, yes.
    - This year, there were problems with low germination rates and rejection of seed lots; seed with low germination rates may still be marketed, while price reductions remain uncertain.

Fertilization

12. **Would you agree with these fertilizer recommendations or do you follow a different fertilization strategy on your farm?**
    - Fertilization of lupins is mainly managed through the crop rotation (organic fertilizers), with limited direct fertilization of lupins.
    - Good experiences have been made with small amounts of digestate for starter N fertilization.

13. **Do you use micronutrient fertilizers for lupins on your farm?**
    - The importance of micronutrients for lupins was not fully known to all participants.
    - Micronutrient fertilizers are used to some extent.
    - Boron is particularly important for good lupin development.

Plant Protection

14. **How do you assess these plant protection recommendations? What experiences have you had in practice?**
    - Herbicides: special attention must be paid to weed control; broadleaf weeds can only be controlled chemically in pre-emergence applications, and late weed infestations cause problems.
    - Fungicides: no applications have been necessary so far.
    - Insecticides: leaf weevil occurs regularly, while aphids are not considered a problem.

15. **Are there particular weeds with difficulties on your farm that also affect the cultivation of lupins? If so, which ones?**
    - Goosefoot species, knotweed species, cornflower.

16. **How do you assess the success of chemical plant protection treatments?**
    - Effectiveness strongly depends on soil moisture and weed pressure and varies between years.

17. **Is it possible to achieve a change in active ingredients through lupin cultivation?**
    - Yes, and this option is actively utilized.

18. **Do you have experience with mechanical weed control in lupins (harrow, hoe)?**
    - Experience is available and mechanical weed control is used as a supplement to chemical crop protection.
    - Lupins are highly sensitive when emerging through the soil surface and should not be harrowed during this period.
    - Challenges include weather dependency, correct machine settings, and high investment costs.
    - Positive yield effects are observed due to nitrogen mineralization and improved soil aeration.

Harvest

19. **Have you had similar experiences regarding the harvesting of lupins?**
    - White lupins mature late, around September 10.
    - White lupins are less prone to pod shattering than narrow-leafed lupins.
    - Harvesting in the early morning or late evening has proven effective.

20. **Are there particular challenges in harvesting lupins?**
    - The late harvest date prevents winter oilseed rape from being grown as the subsequent crop (which is possible after narrow-leafed lupins).
    - The late harvest date is problematic because it coincides with other activities (harvest corn silage, grass mowing, plowing).

21. **Do you dry or clean the lupins on your farm? Do you use other methods to improve storage stability?**
    - Lupins must be dried immediately because green plant material in the harvested product causes rapid heating.
    - For feed use, lupins can be crushed, treated with propionic acid, and stored as silage in plastic tubes; alternatively, they can be stored as whole grains with cold-air ventilation and then crushed later.

Marketing

22. **Do you measure alkaloid content on your farm? Do you experience problems with elevated alkaloid levels (>200 mg/kg for food use, >500 mg/kg for feed use)?**
    - Alkaloid content is not measured on the farms.
    - State-wide analyses generally do not show elevated levels.
    - Breeding programs are working on low-alkaloid varieties, and only seed lots with low alkaloid contents are marketed.

23. **Do you have problems with dark-colored or speckled seeds?**
    - No problems, as white lupins produce light-colored seeds and are not marketed for food use.

24. **Do you have problems meeting other quality standards?**
    - No, since the crop is not marketed for food use.

25. **Are there additional quality requirements for marketing? Are you able to meet these requirements?**
    - Agricultural traders are cautious; immature seeds are considered problematic.

Analysis of the Baseline Rotation in the Region (without Lupins)

- Crop shares should be limited to 25 % per crop; longer intervals between oilseed rape increase yields and reduce crop protection costs.
- Corn silage is used for animal feeding or in biogas plants.
- Costs associated with organic fertilization may not be fully captured in fertilization costs.
- Differences in gross margins between the strongest and weakest crop of approximately 300 €/ha (or more) are considered acceptable.

Analysis of the Protein Crop Rotation in the Region (with Lupins)

26. **How would your crop rotation change if you integrated lupins into your crop rotation?**
    - Introduction of lupins as an additional crop after corn silage
      (a good preceding crop for lupins because of its low residual soil nitrogen levels) and before winter barley (to utilize biologically fixed nitrogen).

Gross margin of lupins:

- Yields and prices correspond to practical experiences with white lupins.
- Seed costs are high (200 €/ha) and represent a barrier to adoption for some farms.
- Inoculants would incur an additional cost of 10 €/ha.

27. **How would you integrate the discussed effects of lupins on the subsequent crops into this calculation (impacts on yield, quality, N fertilization, crop protection, tillage)?**
    - The crop rotation effect of lupins should be considered as described under Question 8.

28. **Would you grow lupins even with lower or no governmental support payments?**
    - Yes, because lupins are required for animal feeding in order to receive premiums for the use of GMO-free feed; without support, the cultivation area would likely be reduced.
    - However, cultivation is only economically viable with support payments.

29. **Considering all operational effects associated with the cultivation of lupins, how do you assess the cultivation of lupins on your farm?**
    - Lupins are an integral component of the crop rotation due to their utilization as on-farm feed source.
    - Through attributable effects (e.g. crop rotation effect, governmental support payments, increased milk price), lupins are competitive with other crops (corn silage, winter barley).
    - Lupins have positive effects on crop rotations and soil structure.
    - Cultivation is associated with challenges regarding sowing and crop protection, but these can be managed through experience.
    - Problems include fluctuating yields, low prices, and limited marketing opportunities.
    - Lupins can also be grown on marginal sites where other crops are no longer feasible, although yields are lower there; white lupins generally require better sites (+30 soil quality points), while narrow-leafed lupins can be grown on poorer sites.
    - The issue of alkaloids complicates their use in animal and human nutrition.
    - Market penetration challenges: although lupins and rapeseed meal cost the same, rapeseed meal is usually preferred because of concerns regarding alkaloid content of lupins, allergenic potential of lupins, the small volumes of lupins available, and the resulting additional storage and handling costs; feed companies show little initiative in incorporating lupins into compound feeds.
    - Due to their allergenic potential, strict separation from non-allergenic products is required, resulting in additional processing effort.
    - Low volumes mean that storage capacities cannot be fully utilized compared with bulk commodities.

30. **How do you evaluate the further development of lupin cultivation on your farm?**
    - Lupin cultivation will remain stable because on-farm utilization is firmly integrated into the farm system, and expansion of lupin area is limited due to low market demand and crop rotation considerations.

31. **By which measures can the cultivation of lupins be promoted on your farm?**
    - Higher prices and secure marketing opportunities.

Profile A-3: Pea Cultivation (*Pisum sativum* L.)



General Characteristics and Appearance

- Grain legume with a climbing to semi-erect growth habit and a relatively shallow root system.
- Protein content of approximately 19 %.
- Valuable source of plant protein for animal feed, human consumption, and seed production.

Soil and Climatic Conditions

- Well adapted to cool temperate climates and tolerates light frost during early growth stages.
- Performs best on well-drained loamy or sandy-loam soils with a pH between 6.0 and 7.0.
- Consistent moisture is important, particularly during flowering, while waterlogging should be avoided.
- Due to the shallow root system, peas are sensitive to drought stress, especially during flowering.

Crop Rotation

- Multi-year breaks between pea crops are recommended to reduce the risk of soil-borne diseases.
- Peas are typically grown after winter cereals such as winter wheat or winter rye.
- Winter wheat is a particularly suitable subsequent crop.
- Positive crop rotation effects include increased subsequent wheat yields, nitrogen fertilizer savings and additional agronomic benefits.

Tillage and Sowing

- A loose, friable seedbed is required; plowing before peas is commonly recommended.
- Sowing should be carried out as soon as the soil is thawed and workable, typically from March to April.
- Recommended plant density is 50–70 plants/m².
- Seeding depth of 6–8 cm is commonly used.

Fertilization

- Nitrogen fertilization is generally not required, as peas can meet a large share of their nitrogen demand through biological nitrogen fixation.
- Nutrient requirements are typically around 25 kg/ha P, 75 kg/ha K, and 10–20 kg/ha S, depending on soil nutrient status.
- Manganese and magnesium can be important on high-pH soils or sites prone to deficiencies.

Plant Protection

- Peas have limited competitiveness against weeds during early growth stages.
- Chemical control options for major weeds, diseases, and pests are limited.
- Harrowing and hoeing can be used for mechanical weed control but are not widely adopted in current production systems.

Harvest

- Harvested between July and August.
- Timely harvest is important to minimize yield losses caused by pod shattering and lodging.

Table A-3: Gross margins (GM) of assessed crops and crop rotations in Funen, Denmark (average 2022–2024 and range).
Source: *agri benchmark* calculations.

		Spring Barley	Spring Barley with Grass Seed	Red Fescue Seed 1	Red Fescue Seed 2	Winter Oilseed Rape	Winter Wheat	Spinach Seed	Winter Wheat 2	PEA	Winter Wheat 3
Revenue	**€/ha**	**1448** ***(1044 - 1987)***	**1448** ***(1044 - 1987)***	**1590** ***(1206 - 2239)***	**1590** ***(1206 - 2239)***	**2141** ***(1777 - 2845)***	**2027** ***(1715 - 2628)***	**2414** ***(1016 - 3477)***	**2027** ***(1715 - 2628)***	**1639** ***(1238 - 2336)***	**2027** ***(1715 - 2628)***
Yield	t/ha	5.5 *(4.0 - 7.0)*	5.5 *(4.0 - 7.0)*	1.3 *(1.2 - 1.7)*	1.3 *(1.2 - 1.7)*	4.0 *(3.6 - 4.6)*	7.9 *(7.3 - 9.0)*	0.9 *(0.4 - 1.6)*	7.9 *(7.3 - 9.0)*	3.1 *(2.2 - 4.2)*	7.9 *(7.3 - 9.0)*
Price	€/t	249 *(231 - 277)*	249 *(231 - 277)*	1188 *(1044 - 1356)*	1188 *(1044 - 1356)*	524 *(465 - 616)*	243 *(223 - 273)*	2459 *(2099 - 2821)*	243 *(223 - 273)*	392 *(362 - 449)*	243 *(223 - 273)*
Revenue By-product	€/ha	84 *(55 - 124)*	84 *(55 - 124)*	-	-	31 *(0 - 92)*	113 *(68 - 171)*	-	113 (68 - 171)	-	113 *(68 - 171)*
Support Payment	€/ha	-	-	-	-	-	-	87	-	87	-
Crop Rotation Effect	€/ha	-	-	-	-	-	-	-	-	345 *(306 - 384)*	-
Direct Cost	**€/ha**	**495** ***(431 - 564)***	**495** ***(431 - 564)***	**545** ***(492 - 611)***	**476** ***(426 - 541)***	**705** ***(608 - 833)***	**679** ***(631 - 767)***	**964** ***(885 - 1021)***	**679** ***(631 - 767)***	**330** ***(296 - 376)***	**679** ***(631 - 767)***
Seed	€/ha	96 *(86 - 105)*	96 *(86 - 105)*	46 *(43 - 48)*	-	82 *(77 - 91)*	96 *(83 - 115)*	-	96 *(83 - 115)*	125 *(105 - 151)*	96 *(83 - 115)*
Fertilizer	€/ha	253 *(204 - 326)*	253 *(204 - 326)*	236 *(210 - 289)*	236 *(210 - 289)*	360 *(288 - 469)*	335 *(292 - 417)*	317 *(256 - 407)*	335 *(292 - 417)*	35 *(25 - 48)*	335 *(292 - 417)*
Pesticide	€/ha	112 *(109 - 118)*	112 *(109 - 118)*	152 *(152 - 153)*	130 *(129 - 130)*	224 *(211 - 237)*	215 *(204 - 225)*	370 *(333 - 403)*	215 *(204 - 225)*	139 *(119 - 153)*	215 *(204 - 225)*
Miscellaneous	€/ha	34 *(32 - 37)*	34 *(32 - 37)*	110 *(85 - 123)*	110 *(85 - 123)*	39 *(29 - 51)*	33 *(31 - 35)*	277 *(145 - 363)*	33 *(31 - 35)*	31 *(24 - 40)*	33 *(31 - 35)*
Gross Margin	**€/ha**	**953** ***(480 - 1556)***	**953** ***(480 - 1556)***	**1045** ***(675 - 1748)***	**1114** ***(745 - 1813)***	**1436** ***(1052 - 2237)***	**1349** ***(1022 - 1997)***	**1451** ***(131 - 2456)***	**1349** ***(1022 - 1997)***	**1309** ***(922 - 2040)***	**1349** ***(1022 - 1997)***
Acreage	%	16	12	9	9	12	17	8	17	0	0
GM Baseline Rotation	**€/ha**	**1208** ***(768 - 1900)***									
Acreage	%	16	6	8	8	12	13	8	13	8	8
GM Protein Rotation	**€/ha**	**1234** ***(797 - 1934)***									

Protocol A-3: Expert Discussion in Funen, Denmark

The expert interview was conducted on February 24, 2026, in an online meeting with a Danish crop production advisor.

Introduction

1. **What are the reasons why farmers in Funen region grow peas?**

   Farmers use peas as feed, mainly in pig production. The pig production has a high consumption of protein coming from soy, which is going up and down in price. Peas have a high content of protein. Therefore it makes sense to replace some of the soy with peas, but only if it gives a better economy. Soy can never be fully replaced with peas, because the protein content is lower.

2. **What challenges are associated with pea cultivation in Funen region?**

   The weather: Peas have a very shallow root system and are very exposed for periods with dry weather, especially the flowering period.

3. **Are the peas used as feed, human nutrition or for seed production?**

   Mainly for feed production. Very few grow peas for human consumption,
   and in a very low scale. Only on special contracts.
   Some farmers are also growing peas for seed production on contracts.

4. **Do cultivation practices differ depending on the intended end use of the peas?**

   For human consumption we will focus more on fungus and insects.
   But overall the practice is the same.

Crop Rotation

5. **After which crops are peas grown, and which crop is usually grown after peas?**

   In Denmark we have a high demand for aftercrops (cover crops). Aftercrops are always followed by a spring crop. Therefore, farmers aim to grow as many winter crops as possible. To keep a good crop rotation pea will mainly be grown after a winter crop with aftercrops e.g. winter wheat or winter rye.
   Peas are a very good crop before winter wheat.

6. **Is experience with pea intercropping available (e. g. peas and winter barley grown together)?**

   Yes. Intercropping is sometimes used on dairy farms as feed. Mostly spring barley and peas are grown together and harvested as roughage. But otherwise not in normal practice.

7. **How is the crop rotation effect of peas assessed?**

   Normally the yield increases with 1.200–1.500 kg/ha in winter wheat after peas.
   The nitrogen fertilizer requirement of winter wheat following peas is reduced by approximately 15 kg N/ha.
   The following soil cultivation after peas prior to wheat seeding could be reduced to harrowing instead of plowing.
   Further positive effects on soil structure and crop diversity by pea cultivation.

8. **How does the cultivation of peas affect labor peaks in the farm?**

Peas can easily be added to crop rotation. Of course it can affect the labor, but not necessarily that much. It always takes more time to shift from one crop to another when seeding, spraying and harvesting. When seeding, it's recommended to drive slowly (about 5 km/h) to ensure a uniform seeding depth. You want a uniform seeding depth to ensure uniform germination of the peas, which makes this part important. This means that it takes longer time to seed peas than grain. When you have a uniform germination, it´s easier to control weeds. Because of the lack of herbicides in Denmark it is normal to spray glyphosate just before the germination of the peas. To ensure a bigger germination of weeds it is normal to have a seeding depth of 6-8 cm. By this depth a big amount of weeds will germinate before the peas. A side effect of this is also to ensure moisture to the peas based on the shallow root system. In spring the soil can easily dry out.

You also need more storage capacity to store the peas. This can sometimes be a problem if there are other crops that you don't want to put in the grain silo.

no main effects on labor peaks during seeding of winter crops in autumn and harvest period of the winter crops in summer

Location and Seeding

9. **Can these seeding recommendations be implemented, or have other experiences been made in practice?**

The goal is a pH of 6.0–7.0 depending on the soil. Light/sandy soil 6.0 and clay 7.0. Too low pH results in fewer nitrogen-fixing root nodules.

Seeding as soon as the soil is thawed and workable. This is more important than the date. In Denmark it will normally be sowed in March and April.

Loose and friable seedbed, very important, always plow before peas.

In Denmark it is recommended to have 50–70 plants/m^2. High amounts of seeds with small seeds.

In Denmark 6–8 cm seeding depth.

No coating available for peas.

10. **Do any problems arise during the seeding of peas?**

Normally not.

Fertilization

11. **Would you agree with these fertilizer recommendations or is a different fertilization strategy followed on the farms?**

No N fertilization is required, as peas fix atmospheric nitrogen. There has been some trials with N fertilization In Denmark, but no positive results.

Peas require 25 kg P, 75 kg K and 10–20 kg S in normal healthy soil. With high contents in the soil the P and K can normally be omitted without yield loss. S should always be added. Mg is also important to add especially in soils with high pH.

Mn is very important if the soil is very lose and in soils with high pH. It is recommended to always apply Mn.

All the fertilizing before seeding, but Mn with the sprayer.

Plant Protection

12. **How do you assess these plant protection recommendations? What experiences are gained in practice?**

In Denmark the biggest problem is the lack of pesticides. Important to spray glyphosate before germination.
In 2025 trials have been made with intercropping, barley and peas, to reduce pests. Small effects on pea aphids, but with no further results. The infection was generally on a low level, so the data are unsure.
Only 2 products with 3 fungicides are available in Denmark. Azoxystrobin and pyraclostrobin with boscalid.
Only 2 insecticides are available. Lambda-cyhalothrin and Pirimicarb. Both will maybe be banned after harvest 2027.

13. **Are particular weeds causing difficulties on the farms that also affect the cultivation of peas? If so, which ones?**

Knotgrass, Rape (canola) and Corn Marigold are the biggest difficulties. It is very important that these weeds don't develop leaves. Must be treated as cotyledons. Other weed species are generally suppressed rather than completely controlled.

14. **How do you assess the success of chemical plant protection treatments?**

The goal is to keep the weeds at an acceptable level. Regarding weeds, Denmark needs efficient herbicides.
Fungus is normally not a big problem. Fungicides cannot eradicate the pathogen, but only keep it on a low level if used early.

15. **Is there an option to rely on active substances on pea cultivation that differ from those used in cereals?**

A good thing about peas is that we can treat against Italian Ryegrass and Blackgrass with Cycloxydim. Denmark has a problem with resistance especially on grass weeds in grain. But resistance with Cycloxydim is escalating.

16. **Is experience with mechanical weed control in peas (harrow, hoe) available?**

Yes, but not in that much in conventional farming.
In organic cropping it is normal to do a shallow harrowing with a special harrow – a weeder. You have to be careful not to harrow too late. This will cost yield.

Harvesting and Marketing

17. Have similar experiences regarding the harvesting of peas been made?

Harvest period between begin and mid-August, the plants should be dry, the pods light brown, and the seeds hard.

Gentle combine harvester settings are required.

It is no longer possible to apply desiccants to peas prior to harvest. Consequently, the crop must ripen naturally before harvesting. The peas themselves may not be problematic, but green and moist weeds can cause difficulties during harvest and subsequent drying.

If the water content is above 14 %, the peas should be dried as soon as possible after harvest. If germination is to be maintained, the drying temperature must not exceed 40 °C. It takes some time for the moisture inside the seed to penetrate to the surface of the seed. Drying too quickly at too high a temperature cannot dry the seeds through and risks bursting the seed coat. Drying is therefore carried out in several stages at a maximum of 40 °C or for longer periods at a low temperature, approximately 25 °C.

Transportation with grain auger can damage the peas. Use belts if possible.

18. Are there particular challenges in harvesting peas?

There can be problems with harvesting if the soil is wet and moist. It can be hard to prevent not to pull up the peas without the roots. The peas and roots will start dragging under the header on the combine. This will mean soil in the combine and cause wear and tear on the equipment.

Another problem is if the crop is lying on the ground, it makes it harder to collect the peas. When it is lying on the ground you want to lower the header to help pick up the peas, but you must be careful with rocks. These will also be picked up by the combine and cause wear and tear, or even start a fire.

19. **Are there quality requirements in marketing (especially for human consumption)? Can the farms meet these requirements?**

For feed:
Water content: At harvest, the water percentage should be low, typically the peas should be dried down to 14–15 % for safe storage, as higher humidity increases the risk of mold and reduced quality.
Cleanliness: There should only be a very small proportion of foreign objects (stones, soil, weed seeds). Dried peas for consumption often require high cleanliness to avoid packing the raw material, which makes drying difficult.
Gentle harvesting: Peas break easily. When harvesting and transporting, drive at low cylinder speed, open bridge and use bucket elevators instead of augers to avoid broken kernels.
Nutritional content: Focus is on a high protein content and a good energy value.
Unwanted substances: Low content of toxins (fungal toxins) and other unwanted substances.
Weed control: Thistle heads, burdock, arrowroot and fennel seeds are examples of weeds that can make harvesting and drying difficult and should therefore be minimized.

For feed the quality requirements are normally not a problem. But if it is for human consumption, there may be a problem with fungus. We may also get a problem with insects and bugs if there are no insecticides available from after harvest 2027.

20. **Does the amount of governmental support payments play a role in the cultivation decision of the farmers?**

Sometimes, but considering all other factors, low pea price, wear and tear, only a few pesticides, storage capacity e.g. the support payments does not play the big role.

21. **Considering all operational effects associated with the cultivation of peas, how do you assess the cultivation of peas for the farms?**

By now it is possible to grow peas on Danish farms, but it is not a high value crop. In the Danish system there are other alternatives that are just as good as peas. The price on the product is too low compared to the operational effects.

22. **How do you evaluate the further development of pea cultivation in the region?**

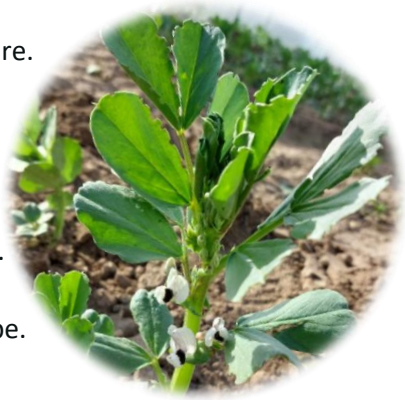
Regarding the new requirements on lowering the waste of N (nitrogen) to the underground and environment, growing peas will not help. On the contrary, peas leave substantial nitrogen residues, which can make it more difficult to apply nitrogen fertilizer to subsequent crops under current regulatory constraints. I think it will be harder to grow peas in Denmark with good economy.

23. **By which measures can the cultivation of peas or legumes be promoted in the region?**

The question is simple. We need to have a higher price on the product.

Profile A-4: Faba Bean Cultivation (*Vicia faba* L.)

General Characteristics and Appearance



- Grain legume with an erect growth habit and broadleaf structure.
- Deep taproots enable access to nutrients in lower soil layers.
- Large pods require consistent levels of moisture to mature.
- Protein content of approximately 29 %.
- Breeding to achieve low levels of ANFs (Vicine & Convicine) important in the context of metabolic disorders such as favism.
- Valuable source of plant protein for animal feed, and for human consumption mostly in Mediterranean regions of Europe.

Soil and Climatic Conditions

- Thrives in heavier soils with the ability to retain sufficient moisture throughout the growing season.
- Requires pH between 6.5–7.0.
- Responds well to high P & K levels.

Crop Rotation

- Multi-year breaks (4–5 years) between bean crops are recommended to reduce the risk of soil-borne diseases.
- Winter wheat is a particularly suitable subsequent crop.
- Positive crop rotation effects include increased subsequent wheat yields, nitrogen fertilizer savings and additional agronomic benefits through reduced plant protection and soil compaction.

Tillage and Sowing

- Sowing earlier in the season reduces yield variability that occurs due to potential drought effects in summer months.
- Soil compaction can reduce yield by up to 40 %, so good soil care and seedbed preparation is important.
- The optimum plant population is 30–35 plants/m².
- Sowing 7–10 cm deep protects the seed and seedlings from birds and herbicides.

Fertilization

- Do not require N, however, if soil P & K index is low (< 3) then crop benefits from supplementation at sowing of a compound fertilizer such as 0:10:20.
- Lime should be applied if pH <6.5.

Plant Protection

- Pre-emergence herbicide recommended to provide a clean seedbed, limited post-emergence options.
- Chocolate spot (B*otrytis fabae*) is an issue where foliage is exposed to humidity for large periods which requires an additional application of fungicide.

Harvest

- Harvest normally between August to September when ground conditions allow.
- Combine setup and time of day important to minimize pod shattering and thus yield losses.

Table A-4: Gross margins (GM) of assessed crops and crop rotations in Leinster, Ireland (average 2022–2024 and range).
Source: *agri benchmark* calculations.

		Winter Barley	Winter Oilseed Rape	Winter Wheat	Malting Barley	Spring Barley	Winter Wheat 2	FABA BEAN
Revenue	**€/ha**	**2268** ***(1922 - 2912)***	**2287** ***(1962 - 2943)***	**2775** ***(2221 - 3726)***	**2479** ***(2056 - 3369)***	**1958** ***(1530 - 2729)***	**2775** ***(2221 - 3726)***	**2372** ***(2054 - 2810)***
Yield	t/ha	8.5 *(8.0 - 8.7)*	4.5 *(4.0 - 4.9)*	10.2 *(9.0 - 11.0)*	7.2 *(6.4 - 8.1)*	7.2 *(6.4 - 8.1)*	10.2 *(9.0 - 11.0)*	5.4 *(5.0 - 6.1)*
Price	€/t	238 *(200 - 306)*	479 *(413 - 570)*	248 *(210 - 316)*	311 *(258 - 385)*	238 *(200 - 306)*	248 *(210 - 316)*	293 *(250 - 347)*
Support Payment	€/ha	250	150	250	250	250	250	459 *(300 - 583)*
Crop Rotation Effect	€/ha	-	-	-	-	-	-	320 *(261 - 394)*
Direct Cost	**€/ha**	**1215** ***(962 - 1473)***	**1064** ***(809 - 1297)***	**1290** ***(1086 - 1520)***	**887** ***(702 - 1075)***	**905** ***(713 - 1096)***	**1290** ***(1086 - 1520)***	**545** ***(503 - 605)***
Seed	€/ha	172 *(160 - 182)*	61 *(46 - 90)*	137 *(124 - 146)*	120 *(105 - 136)*	117 *(105 - 128)*	137 *(124 - 146)*	203 *(196 - 219)*
Fertilizer	€/ha	754 *(494 - 982)*	736 *(477 - 961)*	754 *(494 - 982)*	561 *(373 - 724)*	587 *(389 - 759)*	754 *(494 - 982)*	145 *(106 - 184)*
Pesticide	€/ha	277 *(254 - 295)*	255 *(234 - 278)*	387 *(343 - 441)*	197 *(185 - 204)*	192 *(180 - 199)*	387 *(343 - 441)*	191 *(179 - 197)*
Miscellaneous	€/ha	12 *(10 - 15)*	11 *(8 - 13)*	13 *(11 - 15)*	9 *(7 - 11)*	9 *(7 - 11)*	13 *(11 - 15)*	5 *(5 - 6)*
Gross Margin	**€/ha**	**1053** ***(517 - 1701)***	**1224** ***(709 - 1858)***	**1485** ***(935 - 2461)***	**1592** ***(1031 - 2485)***	**1053** ***(434 - 1822)***	**1485** ***(935 - 2461)***	**1827** ***(1550 - 2285)***
Acreage	%	17	17	17	17	17	17	-
GM Baseline Rotation	**€/ha**	**1315** ***(760 - 2131)***						
Acreage	%	17	17	17	17	-	17	17
GM Protein Rotation	**€/ha**	**1444** ***(970 - 2209)***						