Field lab: LEGUMINOSE intercropping trial 2023-2025

Final report

December 2025

Author: Jerry Alford

Summary

The intercropping field lab was run as part of the Horizon Europe LEGUMINOSE (Legume-cereal intercropping for sustainable agriculture across Europe) project with UK funding from UKRI. Run over three years, the on-farm trials in this field lab compared yield and crop quality between neighbouring monocrops and intercrops. This report is specifically about the UK on-farm trials from 2023-25, with some relevant data from the wider project included for context. Results from this UK trial will be included in a wider LEGUMINOSE project report.

Take home messages

The UK on-farm intercropping trials have indicated that total field yield increases when intercropped, with increases in grain protein and a reduction of pest and disease risk. The increased protein yield from the field can be useful in a livestock system by producing a home-grown ration.

Context

Intercropping is not a new technique but remains a niche activity. The LEGUMINOSE project is looking at the potential to increase its use by looking at some of the barriers which reduce uptake and exploring some of the opportunities for expansion.

Findings

- Increased yield of around 20% in total crop yield and also increases in yield of individual components of the intercrop when compared with the equivalent area of cereal.
- Reduction in disease and pest issues, reducing the need for chemical intervention
- Addition of nitrogen fertiliser reduced the benefit of intercropping.
- Alternate row planting led to higher pulse yield which is of interest when growing pulses for premium markets.

Useful resources

***Agronomy* 2025, *15*(9), 2243; https://doi.org/10.3390/agronomy15092243**

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

Main report

1 Field lab aims

To investigate the benefits of intercropping on crop yield and quality in UK conditions.

2 Background

The UK field lab was part of a Europe wide project, LEGUMINOSE, which is looking at intercropping's effects on soil and crop yield across a range of 9 countries.

3 Methodology and data collection

Trialists planted drill width strips of a cereal-pulse intercrop and 2 neighbouring control strips of the monocrops. Yield and soil data were analysed at harvest. All management decisions, from crops to agronomic management were led by the farmer.

4 Results and discussions

In total 26 farmer plots were planted during the trial with 17 plot results being used in analysis That could have been more but the wet weather in the spring of 2024 prevented some farmers starting the trial. The dry spring of 2025 also prevented drilling and did result in two trial plots being whole cropped to provide animal feed and the loss of some control plots due to the dry conditions. In a couple of other cases, forgetting to drill one of the control plots, or to record and take samples when under weather pressure to drill or combine meant we had incomplete trials. One aspect of the trial was that, because we did not require specific crop mixes, systems or even agronomic practices, many farms tried different practices as well as the control monocrops and intercrop plots, learning as they trialled. Beans were the most popular pulse crop planted in the mixes with peas being the alternative. Most trials were based around spring oats and barley with some winter wheat bean intercrops tried.

Land Equivalent Ratios

In all three of the trial years - 2023, 2024, and 2025 - most trial plots had positive **Land Equivalent Ratios**, meaning that they produced more crop from their plots than from an equivalent area of monocrop. Overall, 2023 and 2024 results were consistent with the usual outcome of intercropping achieving a land equivalent ratio of 1.21 in 2023 and 1.27 in 2024 meaning that 1.27 ha of monocrops would have been needed for the same quantity of product. 2024 was a particularly good year for pulses being wetter than average but 2025 fitted the 'I wish' nature of pulses with the dry weather effecting both crop size and pollination resulting in lower yields although LER's averaged 1.06 (Figure 1), there being a

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

small yield benefit from growing them as an intercrop. This was partly because the yield of pulse monocrops was also poor, which brought down the overall average for the monocrops. Resilience from intercrops, meaning that one or other of the crop's benefits from the weather, indicates that intercrops have a particular role in farming in a changeable and variable climate.

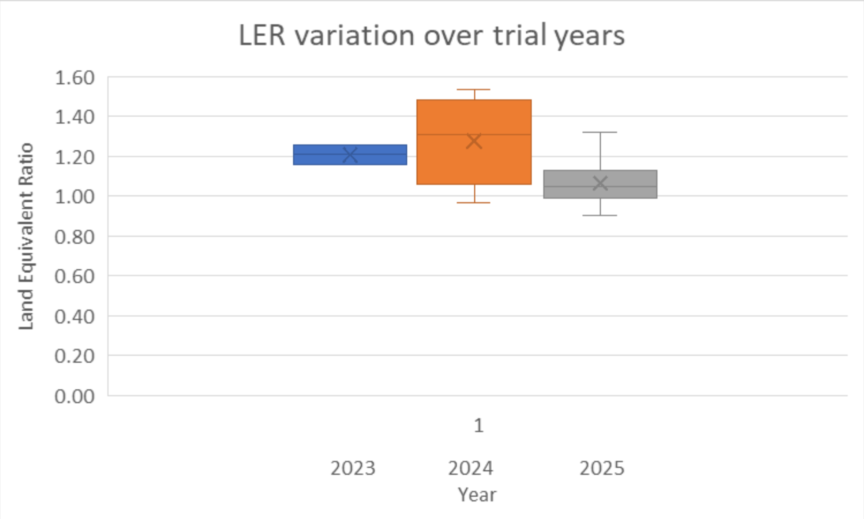


Figure 1 - Variation of Land Equivalent Ratio over 3 trial years

Effect of nitrogen fertiliser

In keeping with farming practices, the pulse was often seen as an additional companion rather than the main crop and so cereal crops were fertilised in some cases. In all cases, whether using digestate, bagged fertiliser or foliar application, increased yield due to fertilisation came at a cost to LER with 2024 crops showing that LER after N application was 1.28 compared with 1.42 for plots with no added nitrogen fertiliser. In 2025, adding N reduced the LER of intercrops to just 1.01 against 1.07 for no applied fertiliser plots. In one farm trial comparison plot with 0 or 140kgN on spring oats, LER dropped from 1.09 to 1.00 for the pea/spring oat intercrop. (Figure 2)

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

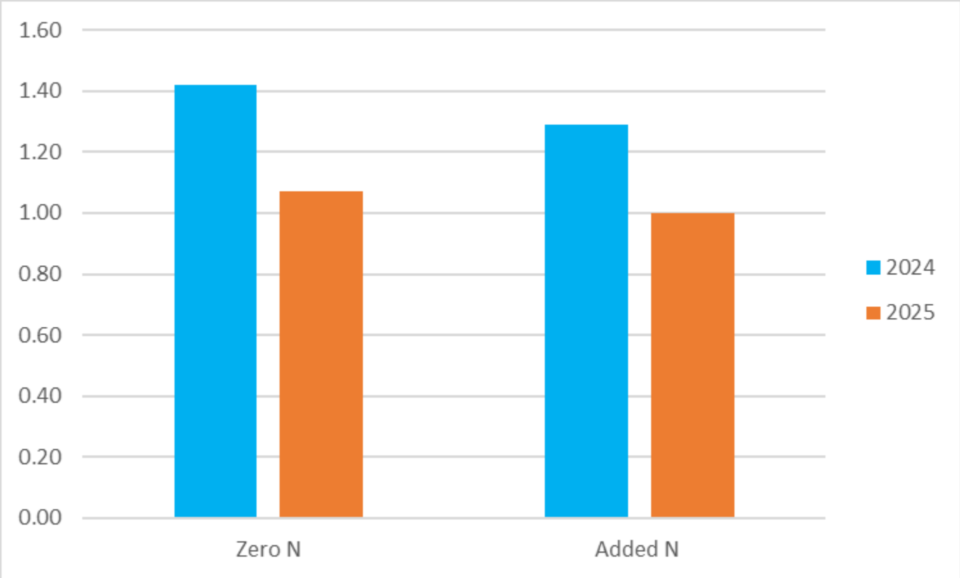


Figure 2 - Effect of nitrogen fertiliser on Land Equivalent Ratio

Yield effects of intercropping

Yield of crops is key to profitability, and one of the benefits of intercrops is the way that the components respond to weather. 2024 was a wet year suiting pulses whilst 2025 was very dry, less suitable to pulses although cereals were less affected. Comparing crop yields directly between mono and intercropped plots is easier if we compare the cereal or pulse yield of the half hectare proportion of the intercrop, with a half hectare yield of monocrop. The resultant graph (figure 3) shows that cereal yields were similar between mono and intercrops in 2024, and monocrop pulses did well. However, in 2025, intercrop cereals outyielded monocrop cereals with the difference in pulse yield being less. As an example of the additional resilience, in one trial area, yield of beans at one end of the field was very poor with oats doing well, and at the other end the opposite situation occurred, meaning that there was a crop to harvest in all parts of the field, which might not have been the case in a monocrop.

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

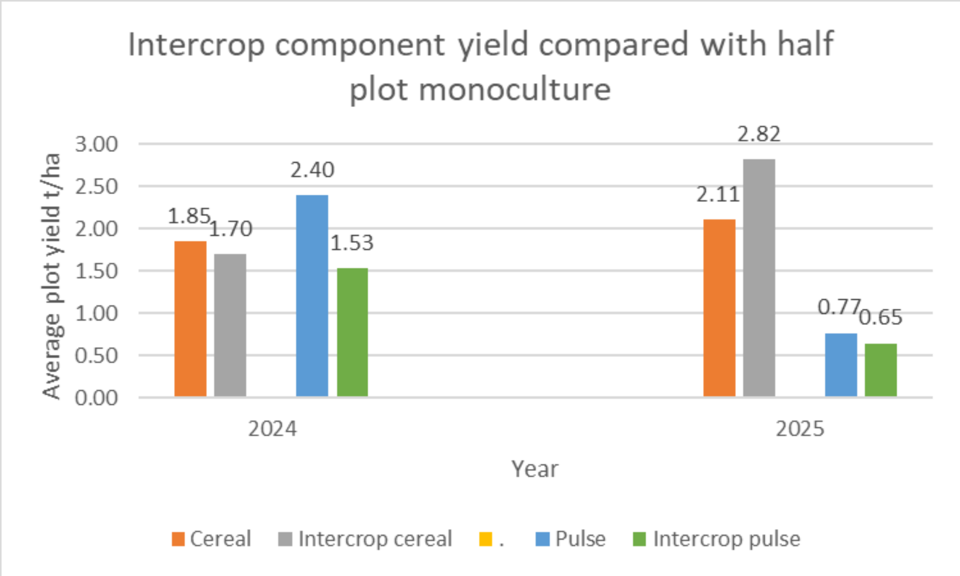
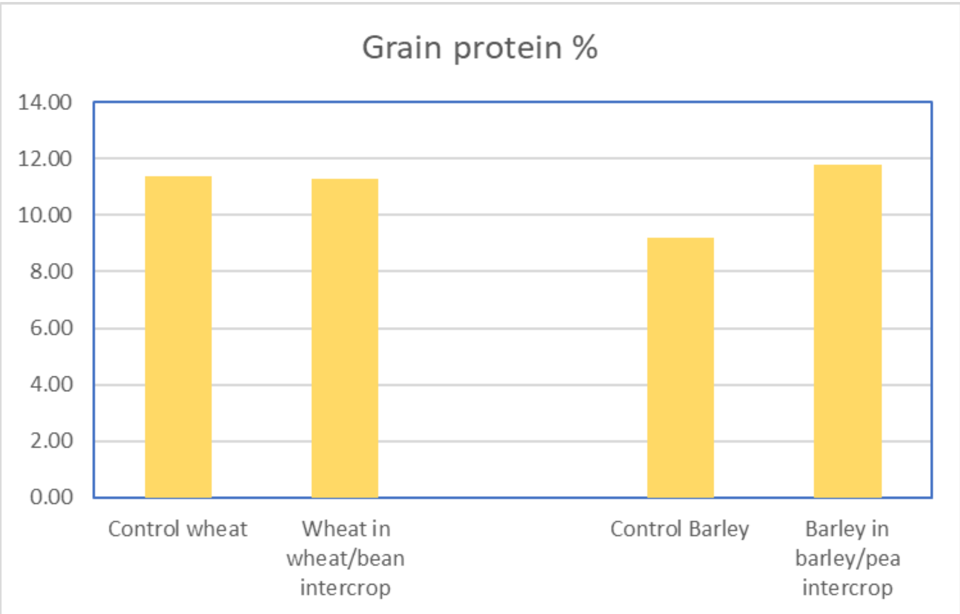


Figure 3 - Comparison of intercrop component yield on equivalent area of monocrop

Grain protein

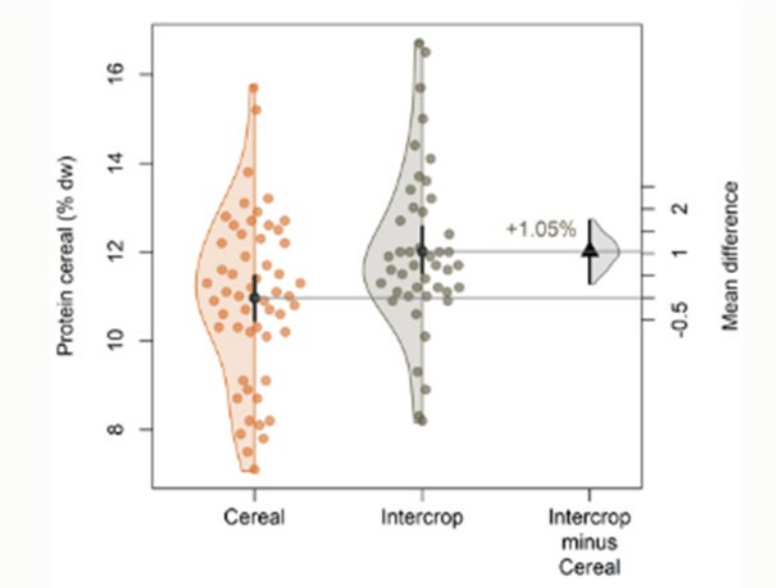
Despite the lower yield in 2025, there remains an indication as we saw in 2023 and 2024, that intercrop cereals have higher grain protein. There were not enough wheat plots to investigate this properly in the 2025 trials, but it was evident in 2024, however despite having higher protein the 2024 intercrop plot still didn't reach milling specification whilst in 2025 both intercrop and monocrop plots did. Pea/barley intercropped grain had 2.5% more grain protein than the monocrop. (figure 4)



This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

Figure 4 - Grain protein in monocrops and intercrops

Although grown to be sold as separated products, the combined sample of roughly 50% peas and 50% barley harvested together produced a mixture with a crude protein of 17.8% Separating the peas from the sample left a clean sample of peas, plus a mix of barley, split peas and hulls. The colour of the split peas was too close a match to allow colour sorting which meant that it was sold as a 12.5% crude protein animal feed for a small premium.



Grain protein levels with intercrops were found to have around 1% more grain protein than monocrops across all the crop mixes in the European trials as part of the LEGUMINOSE project (Figure5)

Figure 5 - Comparison of grain protein across 180 European sites

Whether this is due to lower cereal plant densities, different availability of N late in the season, direct interaction between cereal and legume or differences in nutrient availability in an intercrop isn't clear but there is evidence that In legume-cereal systems, cereals are typically more competitive for soil N sources, causing the legume component to compensate by increasing symbiotic atmospheric N fixation, leading to improved nitrogen use efficiency. Results from the Uk on-farm trials show a pattern that in the absence of additional nitrogen fertiliser, grain protein is higher in intercrops than neighbouring monocrop cereals.

Planting system

One question that has been asked was whether crop benefits would be seen by growing the 2 crops in alternate rows (strips) rather than mixing seeds together and drilling in the same row. One pair of trials looked at this in oats and peas and found that pea yields were higher in alternate rows, although total plot yield was slightly lower. (Figure 6) The implication

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

being that competition for resources was higher when crops were mixed, with the pea potentially being shaded out more by the barley in the dry year. In both plots, there were fewer peas and pods on the ground post-harvest in the intercrops, showing the benefits of scaffolding from the cereal crop.

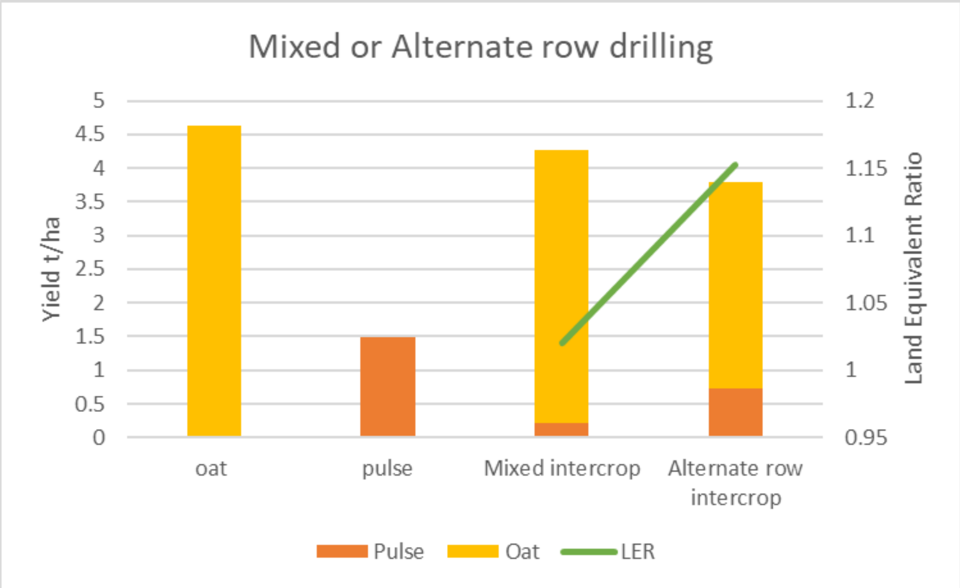


Figure 6 - Effect of alternate row sowing.

In one other trial area which is also part of a wider trial comparing regenerative systems and conventional approaches on a whole rotation, a diverse crop system using an intercrop of oats and beans was compared with monocrop beans either drilled into ploughed or min-tilled ground. The results from one year show an increased yield from intercropping and from ploughing with the intercrop bean yield exceeding the half hectare direct drilled bean yield. (figure 7)   The intercrop also produced a similar quantity of oats.

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

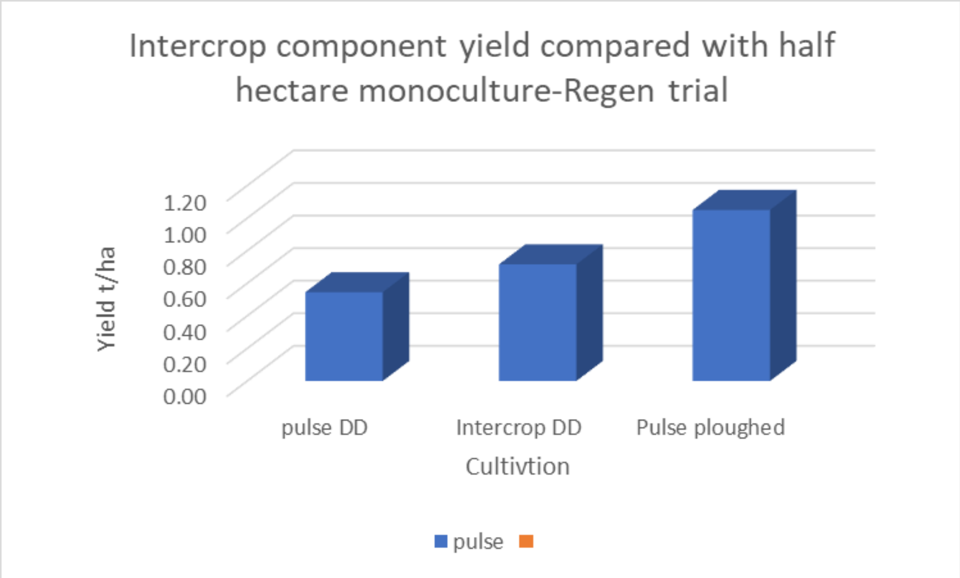


Figure 7 - Comparison of cultivation and intercrop effects on bean yield

Seed rates

Reducing seed rates to 60% of the normal was the guidance for trialists, although they were free to decide their own rates. When seed quality was less than ideal or germination compromised, the resultant lower plant population led to less-than-ideal populations although the advantage of the 2 species mix did mean that total plot yields were maintained, although crop ratios did vary. Oats are the one crop which does adapt to lower seed rates as it is very good at tillering at lower seed rates. Deciding which crop was the priority, whether the pulse or cereal, should influence ideal seed rate. In one trial, 40kg Oats combined with 250kg beans led to 46% higher pulse yield compared to the standard monocrops of 300kg beans and produced 77% of normal oat yield from 160kg Oat seed (Figure 8). Showing that beans benefitted from the nurse crop companion crop with an additional anecdotal benefit of less weed in the plots.

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

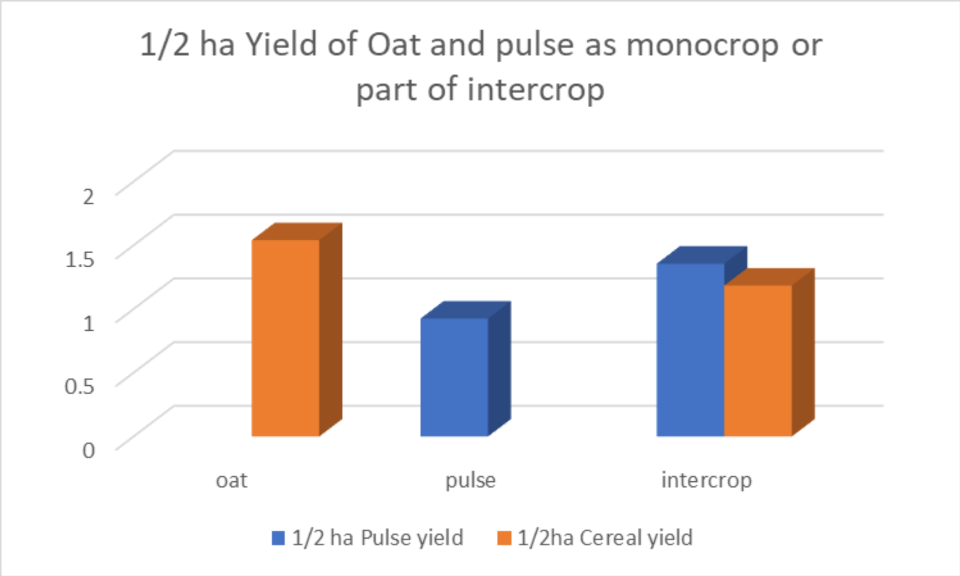


Figure 8 - Effect of lower seed rate on crop yield (180kg for monocrop, 40kg for intercrop)

Pest and disease control

One other perceived benefit of intercrops is a reduction in pest and diseases, because of either disruption of movement through the mixed crops or through an increase in beneficials.

No trialists used any insecticides or fungicides in the trials and only one reported any issues with crop disease but as part of the trial, plots on 2 farms were visited 3 times during the growing season and assessed for plant disease (net blotch in barley), pests (cereal Weevil-Oulema species) and beneficial hoverfly eggs and larvae (Syrphid). Using canes to mark test sites, the same locations were assessed each time and results shown as heat maps.

UK results will be reported separately but in 2024, Czech Republic trials found the following, (Figures 9 and 10). Net blotch severity was found to be more severe in the monocrop with greater than 58% of crops showing severe (3 out of 5) infection on the top three leaves in the monocrop but significantly less severe infection in the intercrop. Severe infection was also more localised in the intercrop.

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

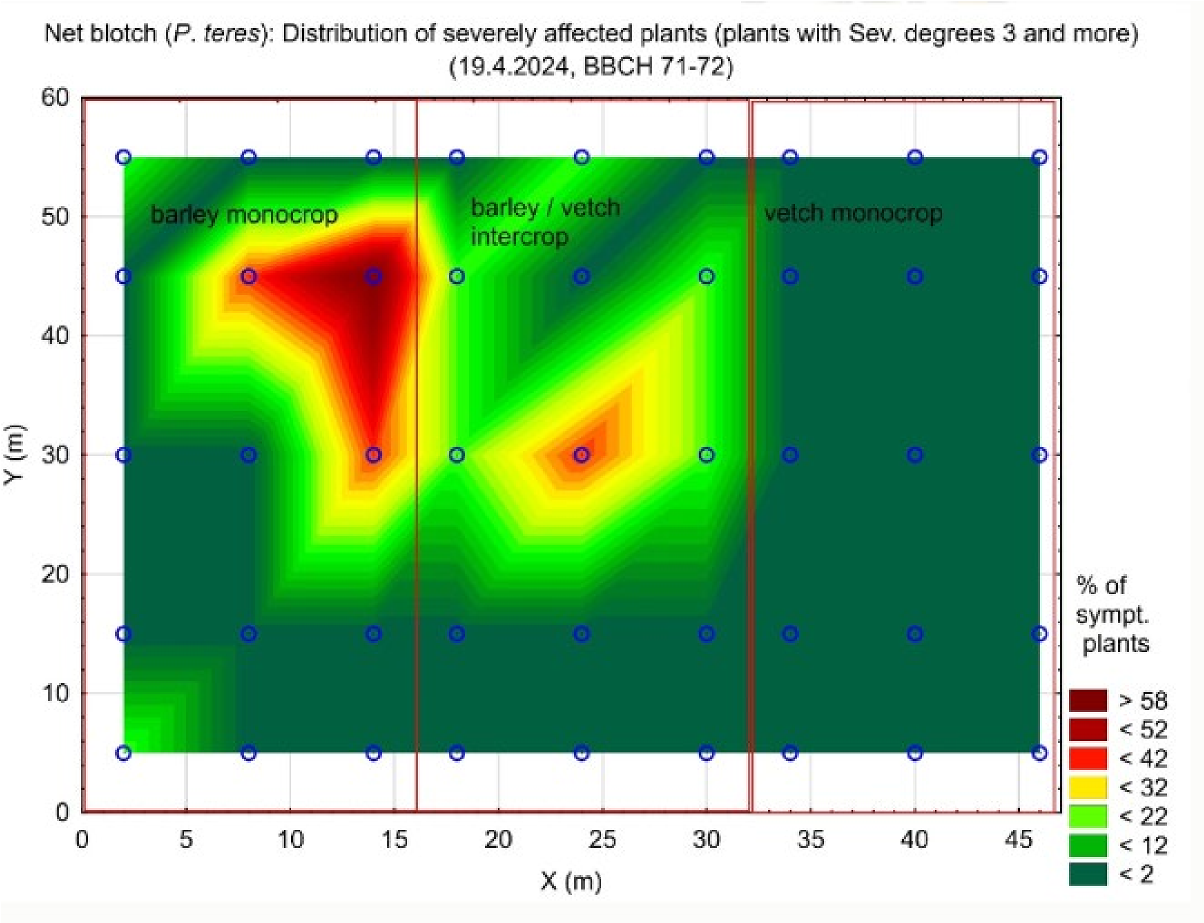


Figure 9 - Heat map of Net Blotch infection in barley and barley vetch intercrop. From Czech Republic trial site

Oulema, cereal Weevil, damage was found on 20.5% of the upper 3 leaves in monocrop barley but only 14.5% of cereal plants in the intercrop.

The Hoverfly analysis showed a higher level of hoverfly eggs and larvae per plant in the monocrop pea crop. Since populations will be linked with feed availability this means that there was more food (aphid) present in the monocrop than in the intercrop and showing the ratio of pests to beneficials, this can be factored into the analysis. With pea aphids affecting plants directly through feeding on sap, and carrying viruses, intercrops are therefore a means of keeping aphid populations down below threshold levels for control. In Figure 10, the red spot shows a high ratio of beneficials to aphids, in an area that had had a fungicidal treatment which is likely to stress the crop making it more susceptible to aphid attack.

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

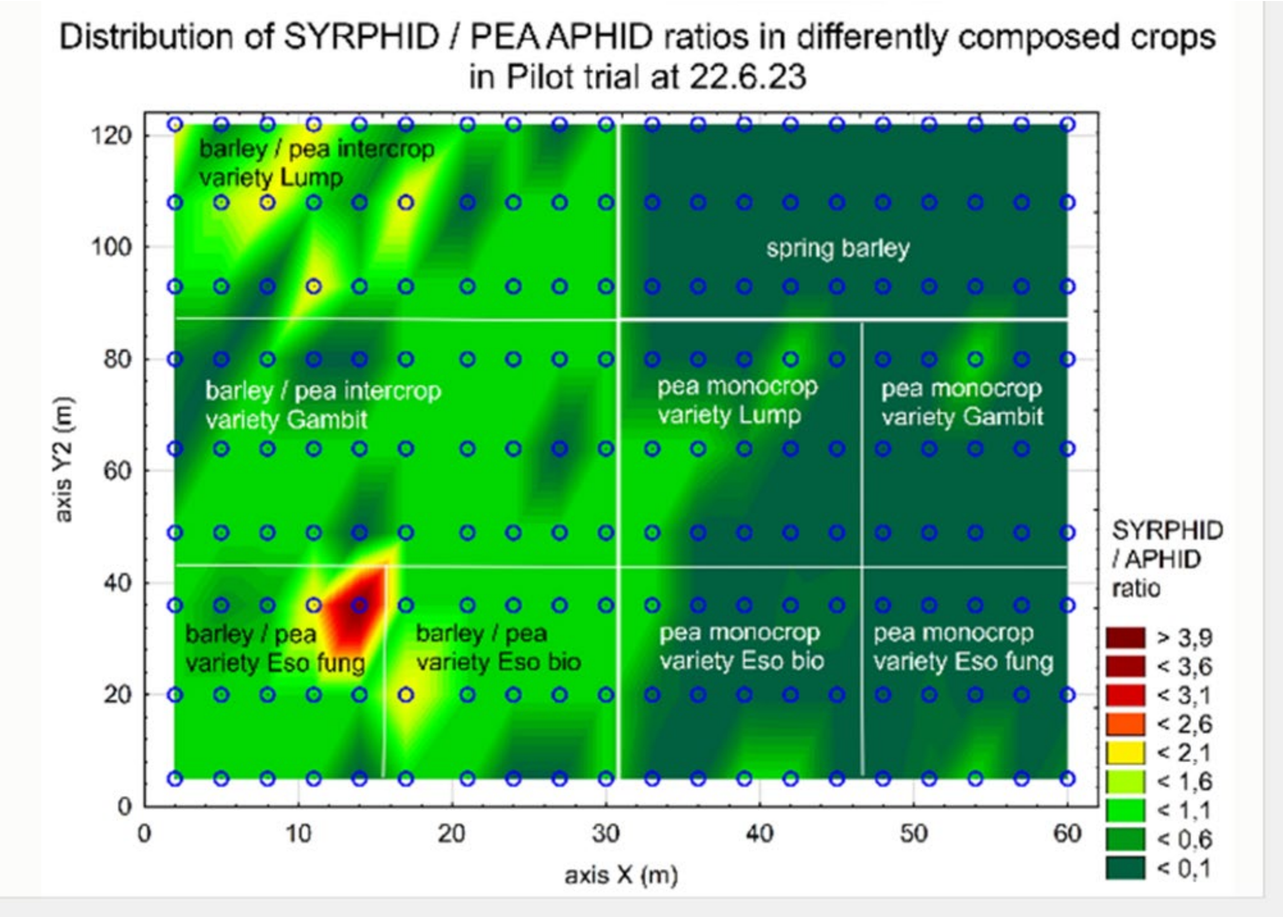


Figure 10 - Heat map of Syrphid/pea Aphid ratios in Czech Republic trial site

In the one UK trial plot, where disease issues were seen, levels of yellow rust in the wheat led to severely reduced yield in the plots and treatment may have been beneficial showing that, in high-risk years, intercropping reduces risk but does not eliminate pest and disease. From an integrated pest management (IPM) perspective, intercropping can be utilised to reduce the requirement for prophylactic treatment and keeping vulnerable crops below thresholds for treatments.

Economics of intercropping

There are additional costs associated with drilling intercrops which will be dependent on drilling system and the proposed market for crops. Total seed costs will likely be higher particularly as pulse seeds are more expensive than cereals, although there will usually be a higher sale price as well.

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

Two planting passes has a cost unless they are part of the seedbed creation such as ploughing and a combination cultivator-drill. Separation of crops will also have a cost although a pass through a normal grain cleaner pre storage is usually adequate to separate for sale, higher levels of cleaning maybe needed for human consumption markets. When grown as animal feed, separation will not be needed, because the combined crop can be milled together, with pricing based on crop ratios. Most of the trial plots were grown without fertiliser or agrochemicals and so comparisons between plot types can be made simply by looking at sale price. Markets for intercrops will influence profitability and where there is a premium available for one of the crops, maximising its potential is essential, for example, through using a cereal as a nurse crop to protect from predation, to reduce disease risk or by providing a scaffold to simplify harvest to reach premium market specifications.

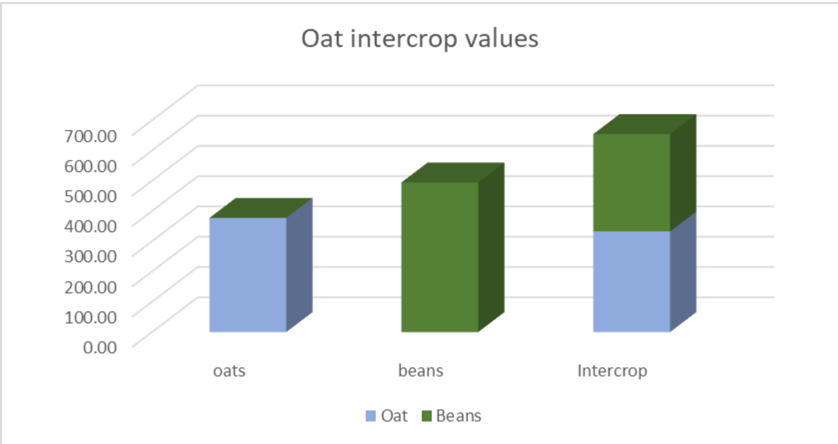


Figure 11 - Comparison of sale prices of intercrops and monocrops 2024

Protein production

One role commonly found for intercrops is production of animal feed as a higher protein whole crop. However, analysis of crop yields from the trials did show that the intercrop, even if harvested at maturity together produced more protein per hectare than an equivalent area of monocrop pulse. (figure 12)

Across all the plots in 2025 the combined samples were calculated to have an average of 15% crude protein, although they peaked in individual plots at 20%. If milling facilities are available, a mixed cereal/pulse blend could be used to produce a whole livestock feed for youngstock, and with suitable balancing for essential amino acids with high quality protein, a ration for dairy cows, pigs or poultry.

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

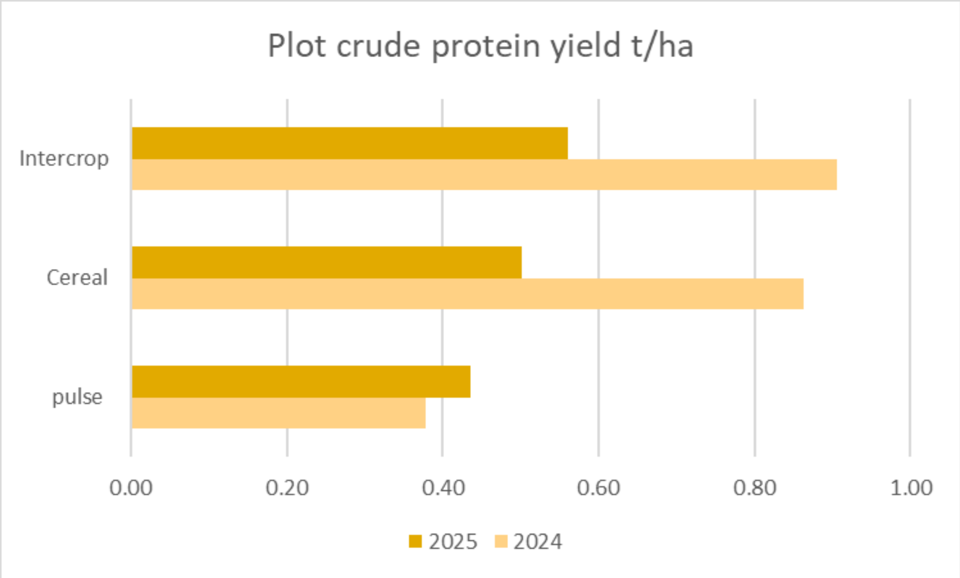


Figure 12 - Average crude protein production from trial plots

Rotational considerations

Both oats and pulses are commonly grown as break crops rather than the main cash crop in a rotation. Conventionally, they are often grown as a take all break, although organically it is an opportunity to bring fertility into the cropped part of the rotation. Weediness is something that is commonly cited as a reason not to grow pulses so the weed reducing nature of intercrops allows pulses to be grown relatively weed free.

The organic farmers in the trial grow intercrops in the later stages of the rotation when fertility has reduced and weed control is trickier. Conventionally farmers see the benefit of an intercrop as providing resilience, or risk reduction, by having mixed crops which can adapt to weather in the year, and the increased LER counters some of the economic issues found with break crop. The double break nature of Boats (beans and oats), as well as potential to sell some products into a premium market makes this an attractive option.

There is concern about how often pulses, and intercrops can be used within rotations with industry guidelines being that one year in 6 as being the ideal. European research as part of the LEGUMINOSE project has shown an increase in both fungal and bacterial populations in intercropped soils and the more diverse communities may well be more resilient to damaging root rots, but research needs to continue.

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

Learnings from trial failures

Not every trial plot produced yield results on all plots, seed quality was one factor but one common issue, particularly in the wet winter /spring of 2024 and the drier winter of 2025, related to drilling depth when drilling mixed seeds in the autumn. Bird damage was a particular problem with Rooks on winter sown beans, and pigeons liking spring sown peas if drilled too shallow. Spring beans are more tolerant of shallower drilling, but winter beans need deeper planting to resist rooks. Drilling alternate rows at different depths or ploughing beans in and then drilling wheat as a separate pass were seen as solutions. When planted as intercrops, pea and bean survival was better compared with monocrops despite lower seed rates and competition.

Crop choice is important in planning intercropping, ensuring that all crops reached maturity at similar times. The natural senescing of maturing crops is influenced by the partner but in the summer of 2024, there were differences between ripeness of beans and oats due to a late summer dry period, meaning some oat yield was lost due to heavy rain before the beans were ripe enough to combine. Selecting early maturing beans and late maturing oat varieties to bring harvest times closer would be a solution, as would be swathing to speed drying.

Harvesting oat and bean intercrop

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.

Innovative Farmers is a programme run by the Soil Association. We are grateful for the support of the King Charles III Charitable Fund, the Rothschild Foundation, the Aurora Trust and our other funders

This trial is part of the LEGUMINOSE Horizon Europe project which is funded by the European Union with UK funding provided by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee. For more information see www.leguminose.eu. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or European Commission. Neither the European Union nor the granting authorities can be held responsible for them.