

Background

The primary goal of arable cropping is to grow high quality harvestable produce for food, feed, fuel or fibre. The challenge is to do this without damaging the environment in which the crop is grown and therefore the prospects of continuing to crop the same land in perpetuity.

Management to minimise or prevent environmental damage (pollution, soil degradation, biodiversity loss) can incur a yield penalty. Yield, quality and financial margins therefore need to be accounted for in assessments of crop system sustainability: to inform incentive payment schemes encouraging uptake of more sustainable cropping practices, or to design a crop system that minimises potential loss of income, particularly in the early stages of transition before the longer-term benefits of a healthy, regulated and resilient crop system can be reaped.



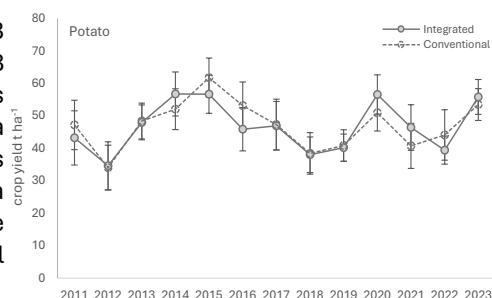
Integrated cropping strategies

At the Centre for Sustainable Cropping, we aim to design a cropping system that can maintain yields with less reliance on agrochemical inputs. We do this by combining management options to simultaneously promote soil health, crop fitness and biodiversity. Together, these enhanced in-field characteristics can improve resource uptake and use efficiency by the crop, increase plant resilience to, and regulate populations of, pests and diseases, and reduce losses through greenhouse gas emissions, leaching and erosion. These effects in turn minimise the crop requirement for mineral fertiliser and crop protection inputs, thereby further enhancing biodiversity and soil health. The regenerative system includes reduced tillage, organic matter amendments, cover and companion cropping, pest and disease threshold monitoring, targeted applications and nutrient budgeting. This is compared in a split-field design with a conventional ploughed system using blanket fertiliser applications and prescriptive, prophylactic crop protection treatments. Trends in systems indicators (soil properties, biodiversity, crop quality and financial margins) are used to review how well the sustainability objectives are met and guide further improvements in system design.

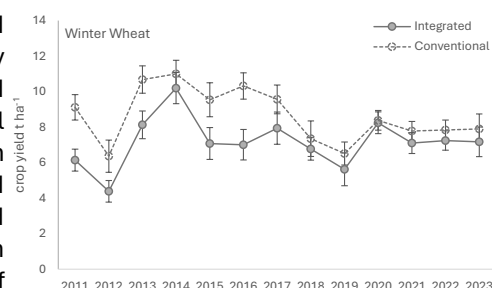


Results from the CSC

Potato. Annual average yield for potato crop from 2011 to 2023 was 43.9 tonnes ha^{-1} in the integrated cropping system and 44.3 tonnes ha^{-1} under conventional management. This difference was not statistically significant either when tested formally using a linear mixed model on data from the first six-year rotation (Hawes et al 2018), or with non-parametric Kruskal-Wallis test on data over two full crop rotations. Potato yields were comparable to the national average for Scotland (40-55 t ha^{-1}) indicating good overall performance in both management systems.



Winter Wheat. Yields were significantly lower in the integrated cropping system, showing a consistent 1 $\text{t ha}^{-1} \text{yr}^{-1}$ yield penalty with an average of 7.1 t ha^{-1} compared to 8.3 t ha^{-1} under standard practice in the first rotation. The ten-year winter wheat national average is 8.6 t ha^{-1} , comparable to the conventional system. In the second rotation, mineral fertiliser requirement was calculated from soil nitrogen supply rather than applied at a standard reduced rate. This helped reduce the yield gap between treatments from 2017 onwards to a non-significant difference of 7.4 t ha^{-1} (integrated) and 7.7 t ha^{-1} (conventional).



Bio4Ag Toolbox Indicators: crop yield

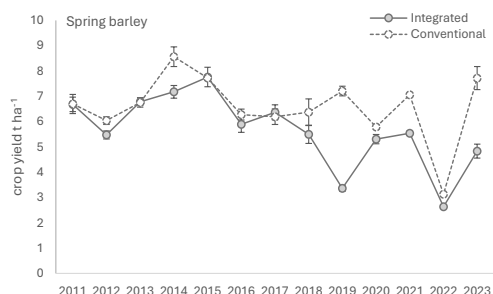
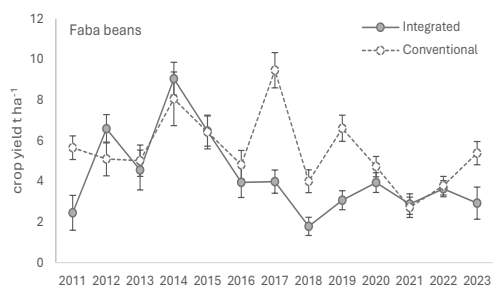
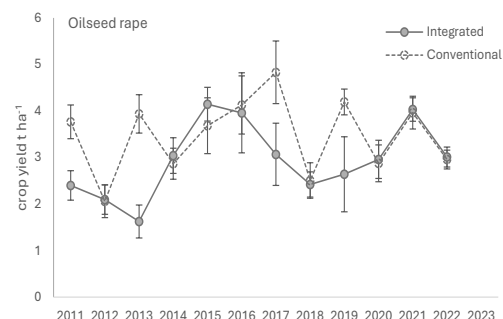
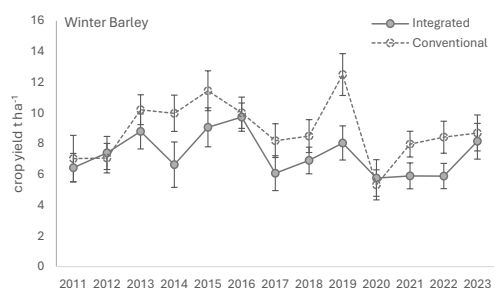
Results from the CSC

Winter Barley. Yields averaged 8.3 t ha⁻¹ in conventional treatments compared to 7.2 t ha⁻¹ in integrated systems, but these differences were only statistically significant in four of the 13 years. The greatest difference between treatments occurred in 2019 where conventional yields were particularly high. Further investigation is required to determine possible reasons for this variation. Both systems produced yields comparable to the national average of 7.5 t ha⁻¹.

Winter Oilseed. Yields of oilseed were not statistically different between treatments across all years (averaging 3.7 and 3.2 t ha⁻¹ in the conventional and integrated treatments respectively). However, lower yields were recorded in some years in integrated treatments due to poorer establishment when direct drilled through the crop residue from the previous cereal crop and, in some fields, disproportionate pest damage where pigeons favoured the integrated side of the field. Issues with establishment were resolved using non-inversion till rather than direct drilling into stubble, providing better seed-soil contact.

Faba Beans. Integrated management had no significant impact on bean yields in the first crop rotation (averaging 5.5 t ha⁻¹ (integrated) and 5.8 t ha⁻¹ (conventional) (Hawes et al. 2018). However, the move from non-inversion tillage to direct drilling in the second rotation may have contributed to a decline in the bean yield in three of the six years to just 3.3 t ha⁻¹ relative to standard crop management. The combination of direct drilling, dry soil conditions during establishment and weedy conditions in some fields can detrimentally affect final yield.

Spring barley. Spring barley yields were 6.1 t ha⁻¹ in integrated system compared to 6.5 t ha⁻¹ in the conventional and a national average of 6.7 t ha⁻¹. This difference was not statistically significant. Lower yields in integrated cropping in some years were most likely caused by competition with the clover companion crop (in 2014), and with weeds (in 2019) where under-sown clover limits the weed control options available. Soil compaction could also be an issue in the second rotation where direct drilling replaced non-inversion tillage. Spring barley is the last crop in the rotation before potato and therefore the longest in no-till. Some varietal effects were detected: cv Sassy has a better rooting structure than other varieties tested and performed better in the integrated system than the conventional, particularly in dry seasons.



Key Findings

- Overall, yields were slightly less in the integrated treatment compared to standard practice. This trend was only statistically significant for winter wheat
- Improvements to system design should focus on:
 - crop residue management (OSR seedling establishment)
 - ameliorating compaction issues in no-till (cereals)
 - minimising weed competition (spring barley)
 - further reducing reliance on mineral fertilisers (legumes)
 - better integration of IPM strategies (all crops)

Useful links

- Roberts et al 2023 Cost-benefit analysis <https://doi.org/10.1016/j.jenvman.2023.117306>
- Maluk et al 2022 Rhizobia for N fixing <https://doi.org/10.1007/s11104-021-05246-8>
- Newton et al 2021 Barley cultivars for no-till <https://www.mdpi.com/2073-4395/11/1/30>
- Abdul-Salam et al 2019 Economic evaluation <https://doi.org/10.1080/21683565.2018.1537986>
- Hawes et al 2018 crop yield and weed effects <https://doi.org/10.3390/agronomy8100229>
- Freitag et al 2018 Impact on vitamin content <https://doi.org/10.1021/acs.jafc.7b03509>