CASE STUDY: PGRO YEAR 1 (ARABLE RESEARCH TRIALS)

Can beans (alone or intercropped) help reduce inputs while maintaining yield and lowering emissions?

PGRO's field trial at Stubton, Lincolnshire in 2023-24 focussed on the effects of winter beans, spring beans, winter wheat and a winter wheat/winter bean intercrop on soil nitrogen dynamics, soil health, greenhouse gas emissions, crop performance, and nitrogen use efficiency.

The specific aims of the trials were:

- To evaluate soil structure and health.
- To evaluate the effects of species and species mixtures in GHG emissions (working with GWCT).
- To evaluate the effects of beans – monocropped and intercropped - on soil nitrogen supply (this will be repeated annually for five years).

It's important to note that the trial was conducted under wet conditions through the winter and spring, which may have affected outcomes.

Trial design and methods

The trial plots were established on sandy clay loam / sandy loam soil following a previous crop of spring barley. Crops were grown in 20 × 50 m non-replicated blocks.

The following cropping systems were compared:

- Winter wheat (sole crop, with and without nitrogen fertiliser)
- Winter beans (sole crop)
- Spring beans (sole crop)
- Winter wheat and winter beans grown as an intercrop

Winter beans (Vespa), spring beans (Lynx), and winter wheat (Gleam) were drilled to standard target populations. In the intercrop, winter beans were drilled at 100% of the sole-crop rate and wheat at 60%. Winter crops were drilled in November 2023 and spring beans in March 2024. Standard pesticide programmes were applied across all treatments. Nitrogen fertiliser was applied to most winter wheat plots, while the intercrop received no nitrogen fertiliser in order to assess reliance on nitrogen fixation from beans.

Soil samples were taken before drilling (November 2023) and after harvest (February 2025) to measure soil mineral nitrogen (SMN), nutrients, carbon, and trace elements. Soil organic matter was assessed using two methods (loss on ignition and conversion from soil organic carbon). Soil nitrogen, moisture and temperature were monitored through the season using probes (some equipment malfunctions were experienced).

Other assessments through the season were crop establishment, height, disease levels and chlorophyll.

Greenhouse gas emissions (CO_2 and N_2O) were measured using portable FTIR equipment. After harvest, straw was retained on half of each block to assess residue effects.

Key findings

Soil nitrogen and organic matter

Soil mineral nitrogen or SMN (available nitrogen) levels were higher before drilling than after harvest across all cropping systems. SMN was consistently higher where straw was removed after harvest, demonstrating that retained straw temporarily immobilised nitrogen.

Total soil nitrogen (which also includes unavailable nitrogen) increased after harvest in all treatments containing beans but declined in sole winter wheat. Soil organic matter levels were generally higher after the trial in bean-based systems, although results varied depending on the method used to measure it. The two SOM measurement methods gave different absolute values, highlighting the importance of consistency in soil monitoring.

Crop growth and disease

Winter beans grown in the intercrop were shorter than those grown as a sole crop. However, rust infection in winter beans was lower in the intercrop, suggesting the wheat acted as a barrier to spread of the disease. In contrast, chocolate spot levels were higher in intercropped beans, indicating that canopy density influenced infection levels negatively.

Height of winter wheat was lower in the intercrop than the sole crop. Disease levels in the winter wheat as an intercrop were significantly lower than in the sole crop, indicating an effect of the winter beans to prevent disease movement.

Soil moisture and greenhouse gases

Soil moisture levels appeared slightly higher in the intercrop through the season, though probe malfunctions limited a full comparison. Carbon dioxide (CO_2) emissions were lower in winter wheat compared with other cropping systems, (see Figure 1) while the nitrous oxide (N_2O) emissions showed no clear pattern during the season. CO_2 is a measure of soil respiration, which appears to be slightly higher in the bean crops compared to the winter wheat. This could be due to the nitrogen fixing capacity of the legumes stimulating microbial activity within the soil under the beans.

Yield, nitrogen and protein

Winter beans produced the highest monocrop yield in 2024 (6.44 t/ha), approximately double that of spring beans (see Figure 2). Winter wheat yields were strongly dependent on nitrogen fertiliser, with fertilised wheat producing the highest yields overall.

The winter wheat/winter bean intercrop produced a combined yield of 6.08 t/ha, but this was dominated by beans with wheat contributing a small proportion. The land equivalent ratio (LER) was 0.895, indicating that the intercrop under-performed compared with growing the crops separately in this season.

Grain nitrogen content and protein yield were highest in winter beans grown as a sole crop. Intercropping reduced nitrogen content in both wheat and beans. Nitrogen harvest index was highest in winter beans and was similar between monocrop and intercrop beans, while intercropped wheat had the lowest

Figure 1: Greenhouse gas emissions

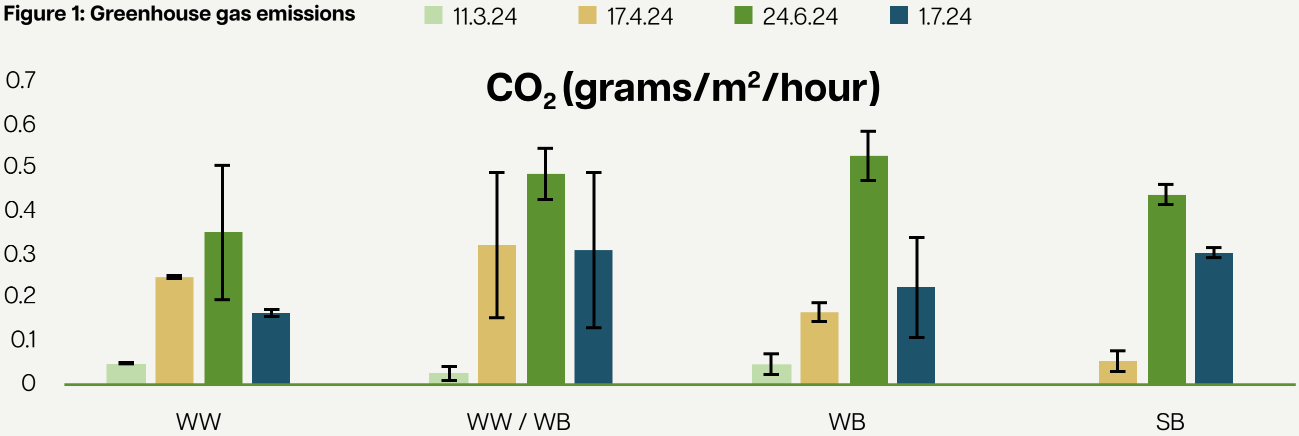
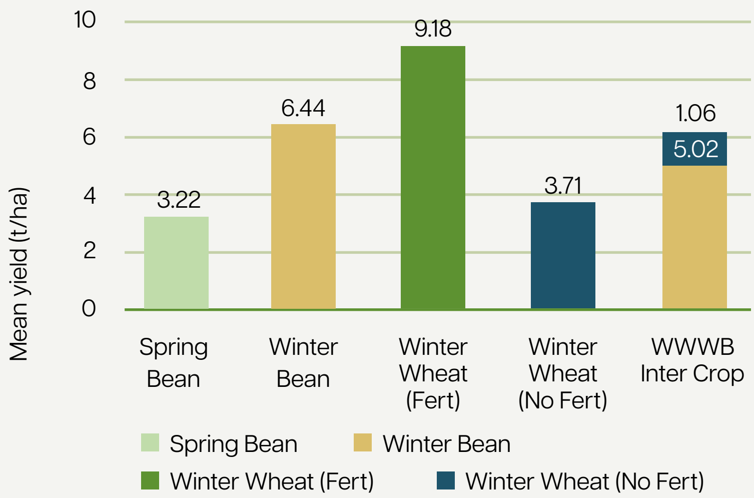


Figure 2: Mean yield (t/ha) of spring beans, winter beans, winter wheat (+/- fertiliser) and winter wheat and winter beans as an intercrop at Stubton in 2024.



Conclusions and next steps

The trial demonstrated that bean-based cropping systems increased soil total nitrogen more than monocropped winter wheat. Straw management also had a clear effect on short-term nitrogen availability, with retained straw reducing measured SMN after harvest. Intercropping provided other benefits for both wheat and beans – namely reduced diseases - but crop height was reduced and, in this season, overall yield was also reduced.

The results highlight both the potential and challenges of using legumes and intercropping to improve nitrogen efficiency. While winter beans performed very strongly in 2024, the winter wheat/winter bean intercrop did not outperform monocrops, emphasising the importance of crop balance, nutrition, and seasonal conditions. Further years of data will be important to understand longer-term soil nitrogen supply, yield stability and greenhouse gas outcomes.

NCS Project

Nitrogen efficient plants for Climate Smart arable cropping systems (NCS) is a four-year £5.9m research programme aiming to enable UK farming to bring about a reduction of 3.4MtCO2e p/a or 54% of the maximum potential for the industry through increased production and use of pulses. Led by PGRO it involves 200 UK farms and 17 partners. The project is funded by the Farming Futures R&D Fund: Climate smart farming, part of Defra's Farming Innovation Programme. Defra is working in partnership with Innovate UK who are delivering the programme.