River Wensum DTC

Research Update 1

WINTER OILSEED RADISH COVER CROPS

MARCH 2019

Cover crops help to reduce diffuse water pollution

The efficacy of cover crops at minimising farm-scale nutrient leaching losses was first assessed during 2013/14 on the Salle Park Estate, Norfolk. The trial area consisted of nine fields covering 143 ha and was divided into three contrasting mitigation blocks. All the blocks had been in winter wheat or winter barley during the 2013 farm year and were going into spring beans in 2014, thus leaving space within the rotation for the planting of a winter cover crop **(Figure 1)**.

Block J (42 ha) was managed by usual farm practice and after harvesting the wheat/barley in August 2013 the fields were left in stubble (i.e. fallow) over winter until the sowing of the spring bean crop in March 2014. Conversely, Blocks P (52 ha) and L (53 ha) were sown with an oilseed radish (*Raphanus sativus*) cover crop (18 kg ha^{-1} seed density) in late August 2013 using a Lemken Karat cultivator and was grown through to mid-January 2014 when it was sprayed off with glyphosate herbicide in preparation for spring bean sowing.

Oilseed radish was chosen because it provides good winter groundcover and has extensive, deep tap roots to help loosen compacted soil and potentially scavenge nutrients at depth.

Since there was some debate among local agronomists about the merits of applying a starter fertiliser to cover crops, this was evaluated by applying 30 kg N ha^{-1} to five of the fields whilst the other two received no fertiliser.

The efficiency of the cover crop at reducing nitrogen (N) and phosphorus (P) losses to soil water and ultimately river water were assessed through monitoring of pollutant concentrations in field drain outflows and porous pots buried 90 cm deep across the trial area. Soil and cover crop vegetation samples were also collected periodically and analysed for nutrient status in order to determine N and P budgets.

The results of the weekly field drain monitoring revealed that the **oilseed radish cover crop successfully reduced nitrate leaching losses discharging into the River Blackwater by 75% under Block P and by 88% under Block L relative to the fallow Block J** during the 2013/14 farm year **(Figure 2)**. Mean nitrate concentrations over this period were 1.8 mg N L^{-1} in the cover crop Block L and 3.5 mg N L^{-1} in Block P, well below the 11.3 mg N L^{-1} WFD drinking water standard.

DEMONSTRATION TEST CATCHMENTS

The Demonstration Test Catchments (DTCs) are a £12.3 m research platform established by DEFRA in 2010 to investigate the extent to which on-farm mitigation measures can cost-effectively reduce the impact of diffuse water pollution on river ecology whilst maintaining food production capacity.

Four DTCs were established across the UK to provide an evidence base for farming in contrasting agricultural systems. These were:

- River Wensum, Norfolk (arable)
- River Eden, Cumbria (upland)
- River Avon, Hampshire (mixed dairy)
- River Tamar, Devon (livestock)

FURTHER DETAILS:
http://www.wensumalliance.org.uk/

FAST FACTS

75-88%

Reduction in nitrate leaching under oilseed radish cover crop

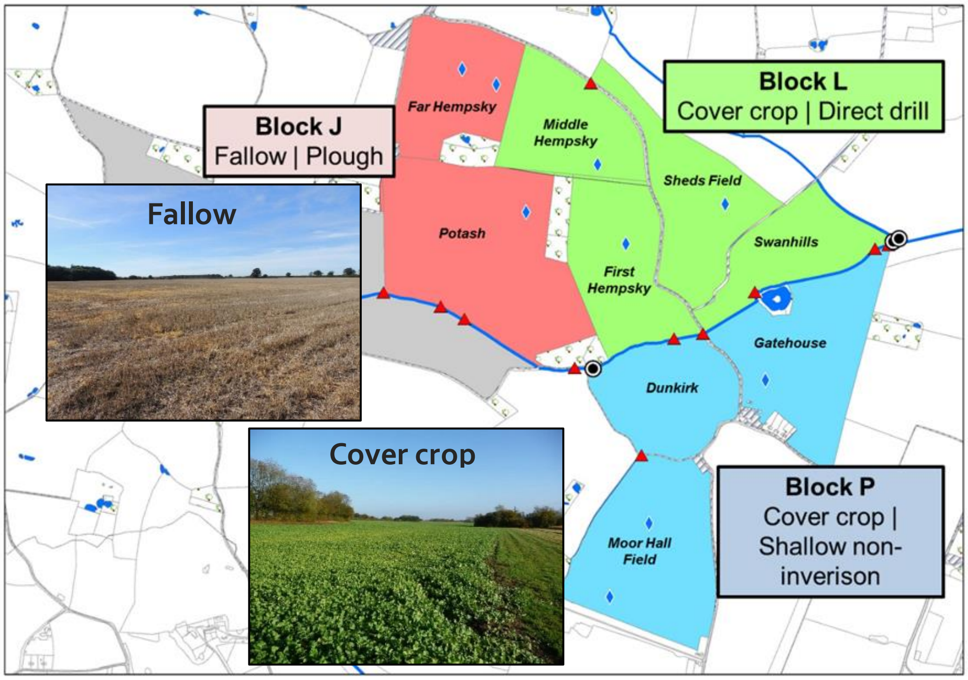


***Figure 1:** Location of the first cover crop trial on the Salle Park Estate in 2013/14, with weekly drain sampling sites (red triangles), porous pot locations (blue diamonds) and bankside monitoring kiosks (black circles) highlighted. Photos taken in November 2013.*

Conversely, mean concentrations were 14.0 mg N L^{-1} in the fallow Block J, with concentrations at or above the drinking water standards for 10 consecutive months.

Furthermore, analysis of soil samples revealed that **soil nitrate concentrations were reduced by 77% at 60–90 cm depth beneath the cover crop**, highlighting the ability of deep rooting oilseed radish to scavenge nutrients from deep within the soil profile and thus mitigate leaching losses.

Nevertheless, corresponding reductions in riverine nitrate concentrations downstream of the trial area were not observed, this despite the trial area covering 20% of the catchment. It is likely that many years of cover crop usage (5–10 years) would be needed to offset the legacy effects of decades of high nitrogen fertiliser input within the catchment before we would start to see significant decreases in river nitrate concentrations.

The oilseed radish cover crop also had no significant impact upon phosphorus losses out of field drains or in porous pot soil water, so would not be recommended as a phosphorus pollution mitigation measure in areas of low lying topography such as Norfolk where leaching, rather than surface runoff, is the main pollution pathway.

Applying a starter fertiliser to the cover crop was found to increase cover crop biomass and nitrogen uptake, however it resulted in net accumulation of nitrogen within the soil, with radish uptake of the fertiliser being lower than the application rate. Growing conditions during autumn 2013 were very favourable with warm temperatures and high solar radiation. This meant the cover crop established very quickly, growing to a height of 50 cm by February 2014, and thus it did not require the 'growth-boost' of a starter fertiliser. Under these favourable growing conditions, applying a starter fertiliser proved detrimental to the objective of reducing nitrogen available for leaching within the soil and such applications would not be recommended under similar conditions.

In terms of farm economics **(Table 1)**, the application and variable costs of establishing and managing the cover crop (£704 – 748 ha^{-1}) were higher than conventional farm practice with fallow (£589 ha^{-1}) due to the additional fertiliser and pesticide added to the cover crop. Nevertheless, **yields 8-12% higher for the 2013/14 spring bean crop in Blocks L (6.24 t ha^{-1}) and P (6.55 t ha^{-1}) compared with Block J (5.80 t ha^{-1}) resulted in only small differences in the overall gross margin between the cover crop (£731 – 758 ha^{-1}) and fallow (£745 ha^{-1}) systems.** Thus, these results demonstrate that farm productivity can be maintained whilst mitigating diffuse nitrate pollution and lend support the wider adoption of winter oilseed radish cover crops to reduce nitrate leaching losses in arable systems.

Second Trial

In autumn 2015, a second cover crop trial was established on the Salle Park Estate on land further west of trial 1, with another five fields added covering an area of 83 ha **(Figure 3).** The purpose of this winter 2015/16 trial was to assess the effectiveness of cover crops in advance of both spring beans and, most importantly, sugar beet in spring 2016. The trial format was as follows:

- **Salle Old Grounds (SOG)** was going into sugar beet in 2016 and was sown with an oilseed radish/rye grass mixed cover crop in September 2015 at 85 seeds m^{-2} density. The oilseed radish variety was Decapo. The eastern half of SOG received an application of turkey manure starter fertiliser whilst the western half had no fertiliser applied. The cover crop was sprayed off with glyphosate in February 2016 prior to sowing of the sugar beet in March 2016 ;
- **Kerdy Green (KG)** and **Stimpsons Potash (SP)** were the sugar beet control fields and were left in stubble over winter;

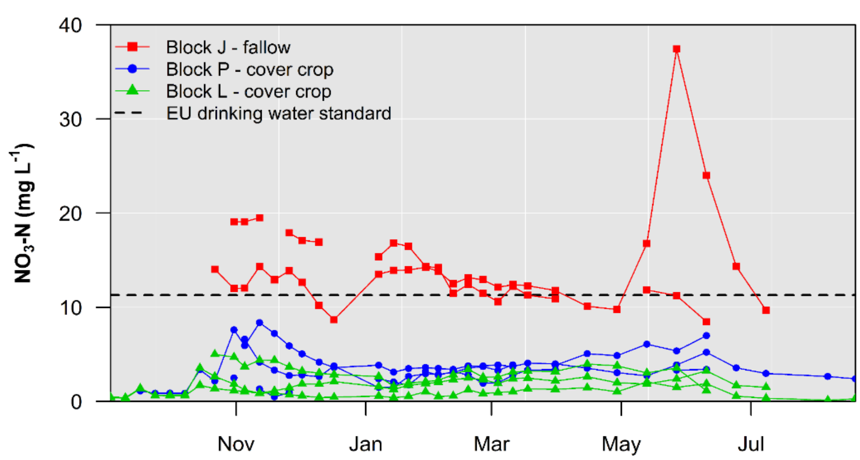


***Figure 2:** Dissolved nitrate concentrations recorded in field drain outflows beneath the cover crop trial area between September 2013 and August 2014.*

Table 1: Summary of the economic performance of the three mitigation measures blocks during the 2013/14 farm year.

Profit/Cost	Mitigation Measure Block (£ ha^{-1}) J	L	P
Yield (t ha^{-1})	5.80	6.24	6.55
Income*	1334	1435	1506
Establishment costs	96	67	128
Application costs	90	120	120
Harvesting costs	85	85	85
Variable costs	318	432	415
Total Costs	589	704	748
Gross margin	**745**	**731**	**758**

**Assuming £230 t^{-1}*

- **Howards Barn (HB)** was going into spring beans in 2016 and was sown with an oilseed radish cover crop at a higher seed density of 165 seeds m^{-2}. The oilseed radish variety was Barracuda. Again the cover crop was sprayed off with glyphosate in February 2016 prior to sowing of the spring beans in March 2016;
- **Sapwells** was the spring bean control field and was left in stubble over winter.

As with the 2013/14 trial, the efficacy of the two cover crop types at reducing nitrogen and phosphorus losses to soil and river water were assessed through monitoring of nutrient concentrations in field drain outflows. Soil and cover crop vegetation samples were also collected periodically and analysed to determine N and P budgets.

The first observation to make is that, in contrast to the 2013/14 trial, **application of a starter fertiliser had a substantial impact upon the growth of the cover crop** in Salle Old Grounds **(Figure 3)**. The wet weight of cover crop leaf biomass in the fertilised half of the field (1.5–2.5 kg m^{-2}) was significantly greater than in the unfertilised half (0.5–1 kg m^{-2}). This in turn impacted upon nitrogen uptake rates, with the cover crop in the fertilised half taking up approximately four times the amount of nitrogen (40–50 kg N ha^{-1}) as the unfertilised half (10–15 kg N ha^{-1}). The reason the starter fertiliser had such a big impact during 2015/16 was because the growing conditions in autumn 2015 were sub-optimal meaning the cover crop struggled to establish without the extra fertiliser. We can therefore conclude that if autumn weather and soil conditions are sub-optimal, and particularly if the cover crop is sown late (i.e. October onwards), then an application of starter fertiliser will likely be necessary to achieve satisfactory cover crop growth.

In terms of water quality **(Figure 4)**, average nitrate concentrations measured in field drain outflows between September 2015 and April 2016 were **82% lower under Howards Barn with the oilseed radish cover crop** (mean = 1.9 mg N L^{-1}) compared to the stubble control fields (mean = 10.4 mg N L^{-1}). This compares very favourably to Salle Old Grounds with the radish/rye grass mixture where **nitrate concentrations were only 17% lower in the unfertilised half** (mean = 8.6 mg N L^{-1}) and **29% lower in the fertilised half** (mean = 7.4 mg N L^{-1}) relative to the control. Thus, we can conclude that a pure oilseed radish cover crop at a high seed density (165 seed m^{-2}) is more effective at reducing nitrate leaching losses than an oilseed radish/rye grass mixture at a lower seed density (85 seed m^{-2}).

The increased growth of the fertilised cover crop on Salle Old Grounds reduced nitrate leaching losses relative to the unfertilised crop, supporting the application of a starter fertiliser during that year. This can be seen most prominently between September and December 2015 when nitrate concentrations on the unfertilised half (dotted blue line in **Figure 4**) are at or above the EU drinking water standard, whereas concentration on the fertilised half remain largely below this level. As the winter progressed into spring, the differences between to two halves of Salle Old Grounds diminished as cover crop growth improved on the unfertilised half and consequently nitrate concentrations reached comparable levels.

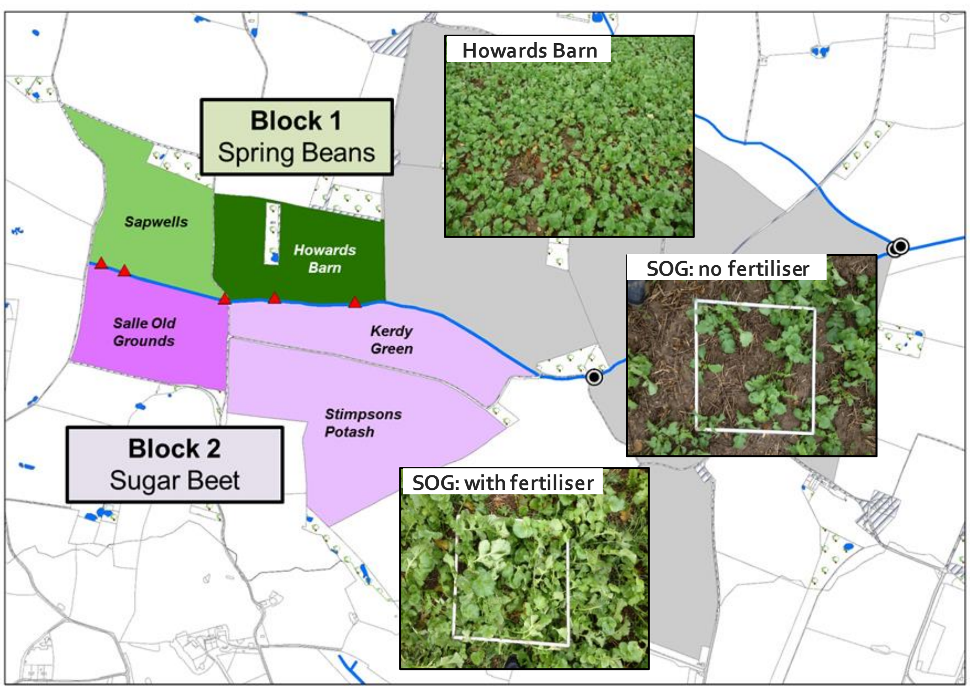
FAST FACTS

33%

Increase in sugar beet yield after a cover crop

With regards to farm economics, there was contrasting performance across the two blocks **(Table 2)**. On block 1, the application and variable costs of establishing and managing the oilseed radish cover crop (£650 ha^{-1}) were again higher than conventional farm practice with fallow (£580 ha^{-1}) due to the additional fertiliser and pesticide inputs to the cover crop. However, in contrast to the 2013/14 trial, yields in the subsequent spring bean crop did not increase

Figure 3: Location of the second cover crop trial on the Salle Park Estate 2015/16, with weekly drain sampling sites (red triangles) and bankside monitoring kiosks (black circles) highlighted. Photos show the cover crop on 3rd December 2015 on Howards Barn and Salle Old Grounds (SOG) with and without a turkey manure starter fertiliser.



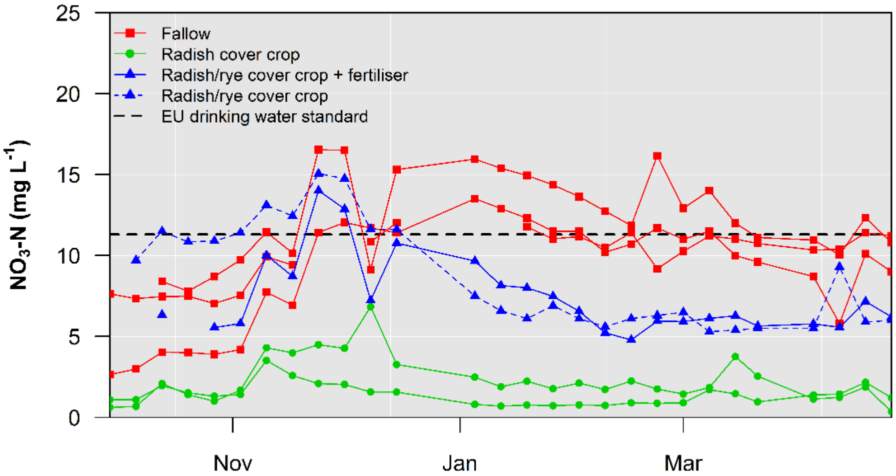


Figure 4: Dissolved nitrate concentrations recorded in field drain outflows beneath the second cover crop trial area between September 2015 and April 2016.

In fact **yields were 20% lower on Howards Barn with the cover crop** (4.7 t ha^{-1}) compared to Sapwells in fallow (5.9 t ha^{-1}). The overall result was net margin 43% lower with the cover crop (£440 ha^{-1}) than without (£775 ha^{-1}). Caution should be exercised in interpreting these results, however, because the Sapwells control field had always been one of the highest yielding fields on the Salle Park Estate and historically has produced higher profit margins than Howards Barn.

In contrast to block 1, block 2 produced a much stronger economic performance in support of cover crops. Slightly higher total costs under the cover crop mixture (£1,041 ha^{-1}) relative to fallow (£1,025 ha^{-1}) were offset by a **massive 33% increase in the yield of the subsequent sugar beet crop** on Salle Old Grounds (85.6 t ha^{-1}) compared to the control fields (64.3 t ha^{-1}). The net result was a **258% increase in overall margin under the cover crop mixture** (£672 ha^{-1}) compared to fallow (£260 ha^{-1}). Most impressively, this occurred on Salle Old Grounds – a field which had historically poor yield performance.

Examination of the soil structure prior to the sugar beet harvest revealed that the cover crop had substantially improved soil tilth and aeration on Salle Old Grounds, opening up pore spaces and reducing waterlogging, thus accounting for the improved sugar beet yield performance.

Sheep grazing *vs.* pesticide

In winter 2018/19, a third cover crop trial was established in the same area as the first trial, with the aim of determining which is a more effective means of destroying a cover crop prior to spring sowing – spraying with pesticide or grazing with sheep. A flock of 300 ewes was brought in to graze the oilseed radish/rye mixed cover crop in December and January, and this was compared against spraying off with glyphosphate by December. *This trial is currently ongoing and further information will be available in summer 2019.*

Table 2: Summary of the economic performance of the cover crop trial during the 2015/16 farm year.

Profit/Cost	Mitigation Measure Block (£ ha^{-1}) Block 1: spring beans Fallow	Block 1: spring beans Cover crop	Block 2: sugar beet Fallow	Block 2: sugar beet Cover crop
Yield (t ha^{-1})	5.9	4.7	64.3	85.6
Bean Income (£ ha^{-1})*	1,355	1,090		
Sugar beet Income (£ ha^{-1})*			1,606	2,141
Establishment costs	107	143	158	147
Application costs	94	85	105	102
Harvesting costs	293	338	562	592
Variable costs	85	85	200	200
Total Costs	580	650	1,025	1,041
Gross margin	**775**	**440**	**260**	**672**

**Assuming £230 t^{-1} for beans & £25 t^{-1} for beet*

Agricultural field drains

River Blackwater, Salle, Norfolk

FOR MORE INFORMATION

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