Portsmouth Water Nitrogen Reduction Trial 2020-23

JANUARY 622

S. Woodley Crop Services
Authored by: Stephen Woodley

S.Woodley Crop Services

Catchment Sensitive Farming
Working together for a healthy environment

Portsmouth Water

Introduction:

Why does every farm apply different amount of Nitrogen fertiliser?

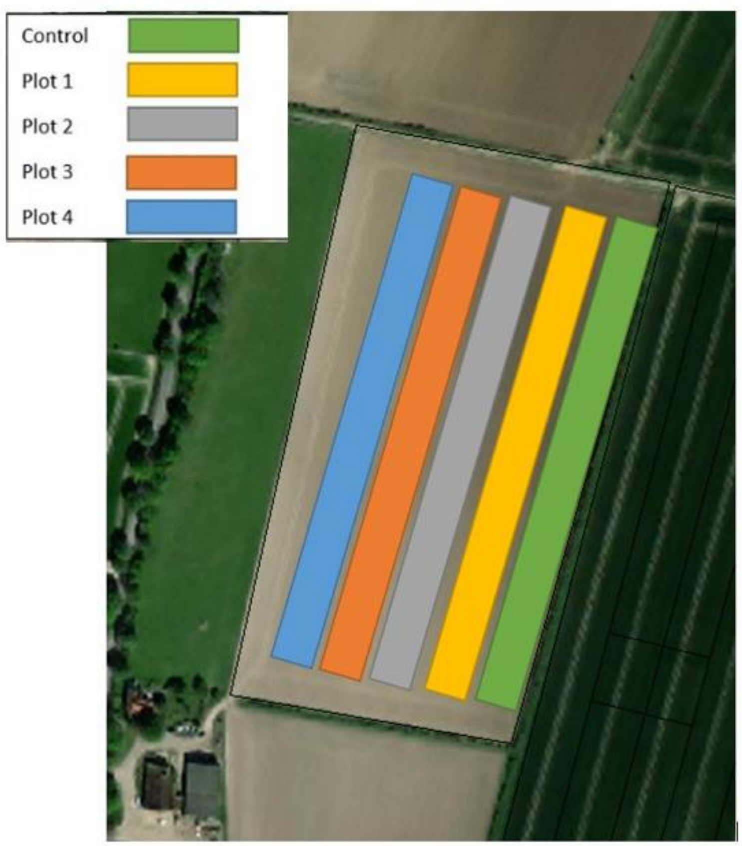
During my early career as an agronomist, I began to realize that every farm has a different plan when it comes to nitrogen fertiliser. Same crop and variety of wheat on the same soil type could see N applications ranging from 220kgN/ha up to 320kgN/ha and the expected yield differences are not always apparent.

With the increasing pressure on the condition of our ground water and the cost of nitrogen fertiliser, it was deemed that we need to improve our understanding of why we apply the amount of N that we do and how the crop changes by cutting back applications. How do we know we are applying the right amount?

Obviously, weather has a massive effect on a wheats potential yield and protein content, so the trial was set to run for three years.

The trial:

Portsmouth Water commissioned S. Woodley Crop Services to conduct an in-depth trial set to understand and measure the effect cutting back N applications has on a crop of winter wheat in terms of yield (income for the grower) and the reduction in nitrogen leaching into the groundwater. A 5ha field trail site planted each year with winter wheat. A chalk loam soil was chosen. The field was planted with stubble turnips over winter. Five different fertiliser regimes were planned looking to cut back applications by:



1. Control (farmers standard practice)
2. 5% reduction total N
3. 10% reduction total N
4. 15% reduction total N
5. 20% reduction total N

Table 1: Nutrient applications on the trial plots:

Plot 1: Control Normal Fertiliser regime Total N: 280kg N/ha.	Treatment 1: 5% reduction Two normal applications of granular fertiliser followed by a reduced third application. Total N: 266kg N/ha	Treatment 2: 10% reduction Two normal applications of granular fertiliser followed by a reduced third application. Total N: 252kg N/ha	Treatment 3: 15% reduction One normal application of granular fertiliser followed by a reduced second and third application. Total N: 238kg N/ha	Treatment 4: 20% reduction One normal application of granular fertiliser followed by a reduced second and third application. Total N: 224kg N/ha
60 Kg N/ha + 60 Kg SO3/ha 316lt /ha of N19 + 19SO3 liquid fertiliser early/mid-march.	60 Kg N/ha + 60 Kg SO3/ha 316lt /ha of N19 + 19SO3 liquid fertiliser early/mid-march.	60 Kg N/ha + 60 Kg SO3/ha 316lt /ha of N19 + 19SO3 liquid fertiliser early/mid-march.	60 Kg N/ha + 60 Kg SO3/ha 316lt /ha of N19 + 19SO3 liquid fertiliser early/mid-march.	60 Kg N/ha + 60 Kg SO3/ha 316lt /ha of N19 + 19SO3 liquid fertiliser early/mid-march.
90 Kg N/ha 261kg /ha of Ammonium Nitrate granular fertiliser mid-April.	90 Kg N/ha 261kg /ha of Ammonium Nitrate granular fertiliser mid-April.	90 Kg N/ha 261kg /ha of Ammonium Nitrate granular fertiliser mid-April.	69 Kg N/ha 200kg /ha of Ammonium Nitrate granular fertiliser mid-April.	62 Kg N/ha 180 kg /ha of Ammonium Nitrate granular fertiliser mid-April.
90 Kg N/ha 261kg /ha of Ammonium Nitrate granular fertiliser May.	76 Kg N/ha 220kg /ha of Ammonium Nitrate granular fertiliser May.	62 Kg N/ha 180kg /ha of Ammonium Nitrate granular fertiliser May.	69Kg N/ha 200kg /ha of Ammonium Nitrate granular fertiliser May.	62 Kg N/ha 180 kg /ha of Ammonium Nitrate granular fertiliser May.
40 Kg N/ha 116kg / ha of Ammonium Nitrate granular fertiliser late May.	40 Kg N/ha 116kg / ha of Ammonium Nitrate granular fertiliser late May.	40 Kg N/ha 116kg / ha of Ammonium Nitrate granular fertiliser late May.	40 Kg N/ha 116kg / ha of Ammonium Nitrate granular fertiliser late May.	40 Kg N/ha 116kg / ha of Ammonium Nitrate granular fertiliser late May.

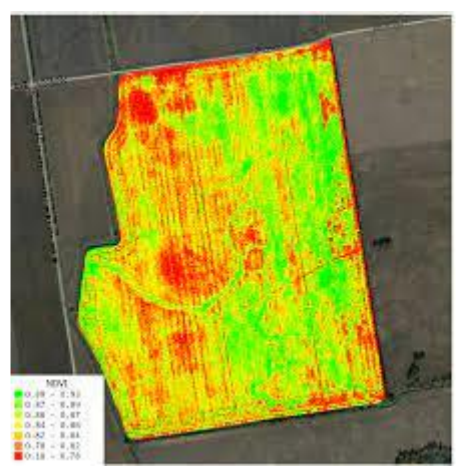
Methodology:

Soil Sampling:
Soil mineral nitrogen sampling was carried out in February prior to any organic manure applications to set a baseline of nitrate levels within the soil. P, K, Mg and OM samples were also taken to understand the variability across the field. SMN samples where repeated after harvest and again in late February each year.

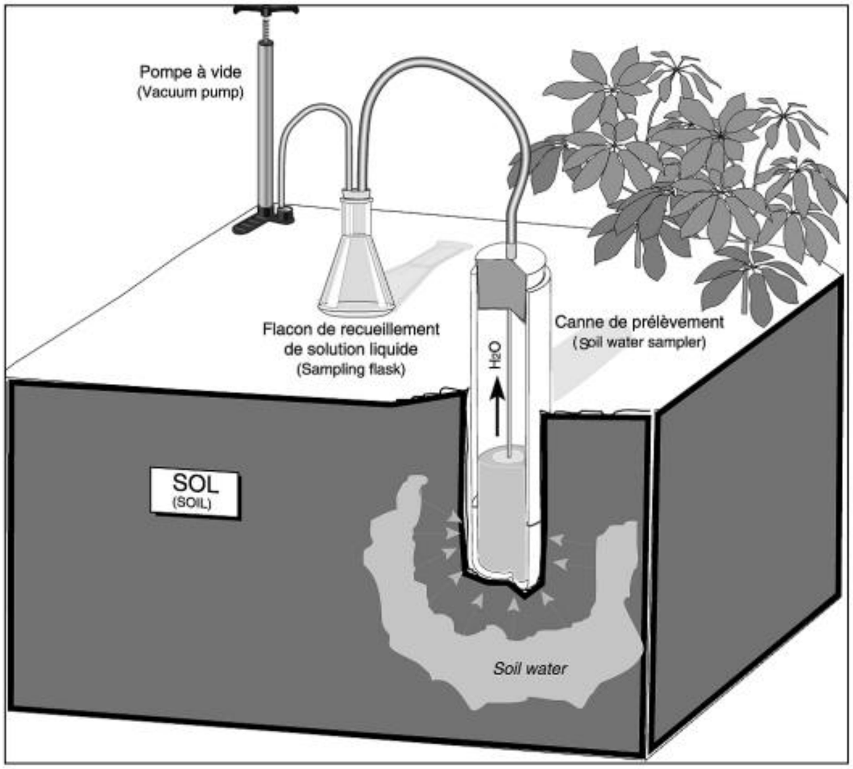
Visual differences:
Site visits were made throughout the growing season to determine any differences in wheat growth.

Tissue Samples:
Tissue samples were taken each month March-June to measure any potential nutrition deficiencies in the plants.

Satellite Biomass Imagery:
Weekly satellite images to monitor any potential changes in GAI across the trial plots.



Yield and grain analysis:
Yield data gathered at the point of harvest and grain analyzed for protein content.



Porous Pots:
Twelve porous pots were installed in each treatment, giving a total of 48 porous pots across the trial. Porous pots were sampled once every two weeks from the beginning of October through to the end of February. The water samples gathered from the porous pots were analyzed as fresh samples for nitrate levels (mg/l) which provided an excellent indication of the amount of nitrate leaching through the soil profile.

Table 2: SMN (Soil Mineral Nitrogen) Results 2020-2021:

Field Reference	Feb 2020 SMN (kgN/ha)	September 2020 SMN (kgN/ha)	January 2021 SMN kgN/ha)
Control	20.4	27.7	25.4
Plot 1 (5%)	20.8	29.5	26.9
Plot 2 (10%)	27.7	30.4	22
Plot 3 (15%)	31.8	24.2	25.8
Plot 4 (20%)	36.9	25.4	85
Average	27.52	27.44	37.02

Table 3: SMN (Soil Mineral Nitrogen) Results 2021-2022:

Field Reference	Feb 2021 SMN (kgN/ha)	September 2021 SMN (kgN/ha)	January 2022 SMN kgN/ha)
Control	28	69.3	27.6
Plot 1 (5%)	30	51	27.9
Plot 2 (10%)	29	52.7	27.8
Plot 3 (15%)	26	29.8	22.8
Plot 4 (20%)	26	67.8	27.6
Average	27.8	54.12	26.74

Table 4: SMN (Soil Mineral Nitrogen) Results 2022-2023:

Field Reference	Feb 2022 SMN (kgN/ha)	September 2022 SMN (kgN/ha)	January 2023 SMN kgN/ha)
Control	50	63	42
Plot 1 (5%)	36	53	37
Plot 2 (10%)	39	72	46
Plot 3 (15%)	61	60	38
Plot 4 (20%)	59	74	30
Average	49	64.4	38.6

Table 5: Tissue Sample Results 2020:

SAMPLE	N Reduction %	Average N Content in plant N:S Ratio % **31-03-2020**	Average N Content in plant N:S Ratio % **30-04-2020**	Average N Content in plant N:S Ratio % **05-06-2020**	Combined Average N:S Ratio %
Control	0	4.17	3.92	1.59	3.23
Plot 1	5	4.18	3.95	1.71	3.28
Plot 2	10	4.51	3.96	1.85	3.44
Plot 3	15	4.59	3.84	1.75	3.39
Plot 4	20	4.65	3.78	1.64	3.36

Table 6: Tissue Sample Results 2021:

SAMPLE	N Reduction %	Average N Content in plant N:S Ratio % **06-04-2021**	Average N Content in plant N:S Ratio % **11-05-2021**	Average N Content in plant N:S Ratio % **03-06-2021**	Combined Average N:S Ratio %
Control	0	3.76	3.42	2.18	3.12
Plot 1	5	3.67	2.84	2.32	2.94
Plot 2	10	3.65	3.1	2.28	3.01
Plot 3	15	3.66	2.61	1.81	2.69
Plot 4	20	3.83	2.98	2.29	3.03

Table 7: Tissue Sample Results 2022:

SAMPLE	N Reduction %	Average N Content in plant N:S Ratio % **05-04-2022**	Average N Content in plant N:S Ratio % **06-05-2022**	Average N Content in plant N:S Ratio % **21-06-2023**	Combined Average N:S Ratio %
Control	0	2.61	2.45	1.58	2.21
Plot 1	5	2.74	2.32	1.67	2.24
Plot 2	10	3.09	2.14	1.8	2.34
Plot 3	15	2.59	2.48	1.55	2.21
Plot 4	20	2.57	2.3	1.42	2.1

Yield (t/ha):

Year	Control	Plot 1 (5%-)	Plot 2 (10% -)	Plot 3 (15%-)	Plot 4 (20%-)
2020	13.2	13.02	13.18	12.39	12.6
2021	9.8	9.97	9.6	9.82	9.5
2021	11.46	11.45	11.13	11.54	11.3
Average	**11.48**	**11.48**	**11.3**	**11.25**	**11.1**

Protein (%):

Year	Control	Plot 1 (5%-)	Plot 2 (10% -)	Plot 3 (15%-)	Plot 4 (20%-)
2020	10.82	11.23	11.17	11.02	11.58
2021	12.88	12.21	11.48	11.26	10.77
2021	13.45	12.84	13.22	12.3	11.63
Average	**12.38**	**12.09**	**11.95**	**11.53**	**11.33**

Porous Pot Results Oct 2020 – Jan 2021:

Control		Plot 1 (5%)		Plot 2 (10%)		Plot 3 (15%)		Plot 4 (20%)	
Date of sample	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**
04/11/2020	8.1	04/11/2020	0.1	04/11/2020	12	04/11/2020	3.5	04/11/2020	2
19/11/2020	6.65	19/11/2020	4.625	19/11/2020	0.6	19/11/2020	10.3	19/11/2020	1.775
03/12/2020	2.1	03/12/2020	0.3	03/12/2020	0.5	03/12/2020	1.725	03/12/2020	0.1
16/12/2020	1.15	16/12/2020	0.2	16/12/2020	0.1	16/12/2020	0.1	16/12/2020	0.1
29/12/2020	0.1	29/12/2020	0.1	29/12/2020	0.1	29/12/2020	0.1	29/12/2020	0.1
14/01/2021	0.6	14/01/2021	0.1	14/01/2021	0.1	14/01/2021	0.1	14/01/2021	0.1
02/02/2021	0.1	02/02/2021	0.125	02/02/2021	0.1	02/02/2021	0.1	02/02/2021	0.1
11/02/2022	0.26	11/02/2022	0.975	11/02/2022	0.5	11/02/2022	1.13	11/02/2022	0.1

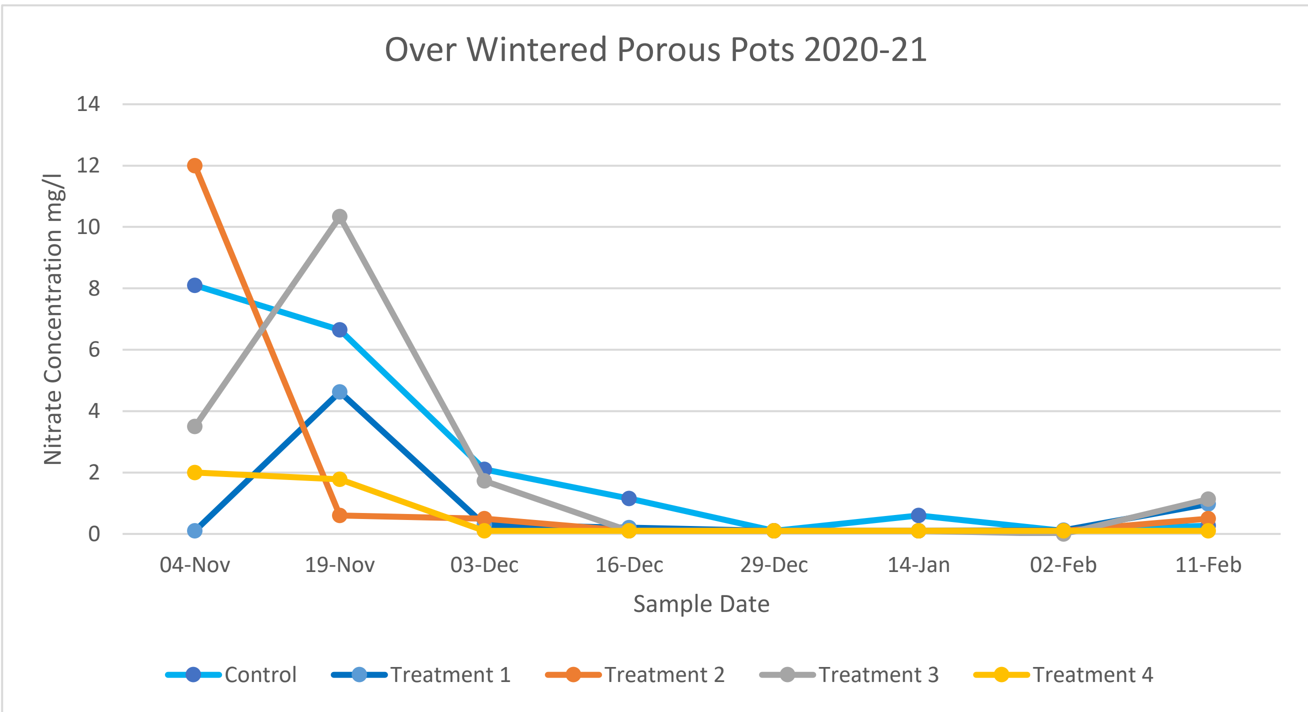


Figure 1. Porous pot results 2020-2021

Porous Pot Results Oct 2021 – Jan 2022:

Control		Plot 1 (5%)		Plot 2 (10%)		Plot 3 (15%)		Plot 4 (20%)	
Date of sample	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**
14/10/2021	29.68	14/10/2021	22.9	14/10/2021	12.4	14/10/2021	19.07	14/10/2021	8.53
11/11/2021	14.27	11/11/2021	12.75	11/11/2021	10.33	11/11/2021	9.25	11/11/2021	3.8
01/12/2021	18.7	01/12/2021	15.17						
14/12/2021	4	14/12/2021	8.85	14/12/2021	0.25				
05/01/2022	0.1	05/01/2022	1	05/01/2022	0.4	05/01/2022	1.9	05/01/2022	0.1
11/01/2022	9.93	11/01/2022	0.1			11/01/2022	0.2	11/01/2022	0.3
21/01/2022	1.87	21/01/2022	0.1	21/01/2022	0.85			21/01/2022	0.1

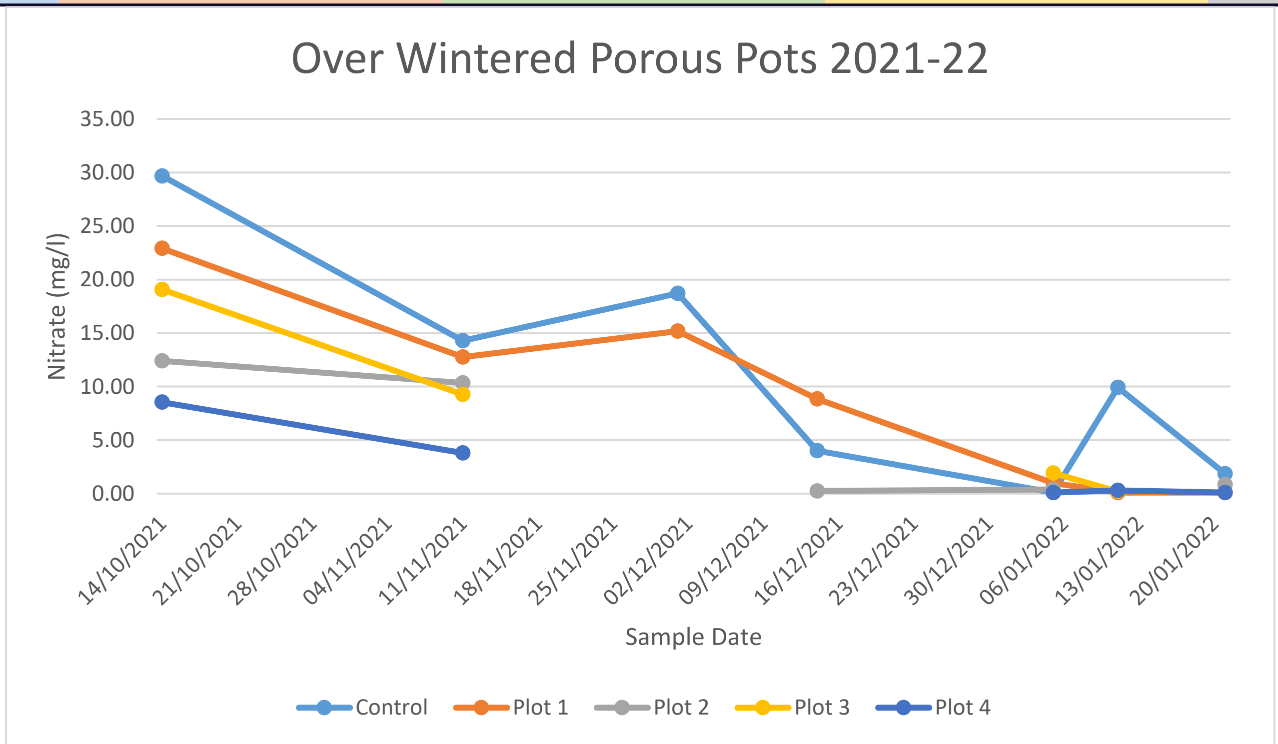


Figure 2. Porous pot results 2021-2022

Porous Pot Results Oct 2022 – Jan 2023:

Control		Plot 1 (5%)		Plot 2 (10%)		Plot 3 (15%)		Plot 4 (20%)	
Date of sample	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**	**Date of sample**	**Nitrate (mg/l)**
17/11/2022	12.65	17/11/2022	8.90	17/11/2022		17/11/2022	4.20	17/11/2022	2.68
30/11/2022	11.33	30/11/2022	5.03	30/11/2022	3.10	30/11/2022	3.43	30/11/2022	1.67
19/12/2022	7.30	19/12/2022	3.43	19/12/2022	1.37	19/12/2022	3.18	19/12/2022	1.43
06/01/2023	11.33	06/01/2023	3.20	06/01/2023	2.13	06/01/2023	3.05	06/01/2023	1.70
18/01/2023	6.45	18/01/2023	3.88	18/01/2023	5.15	18/01/2023	5.83	18/01/2023	2.97
23/02/2023	7.57	23/02/2023	6.70	23/02/2023	7.77	23/02/2023	5.43	23/02/2023	7.40

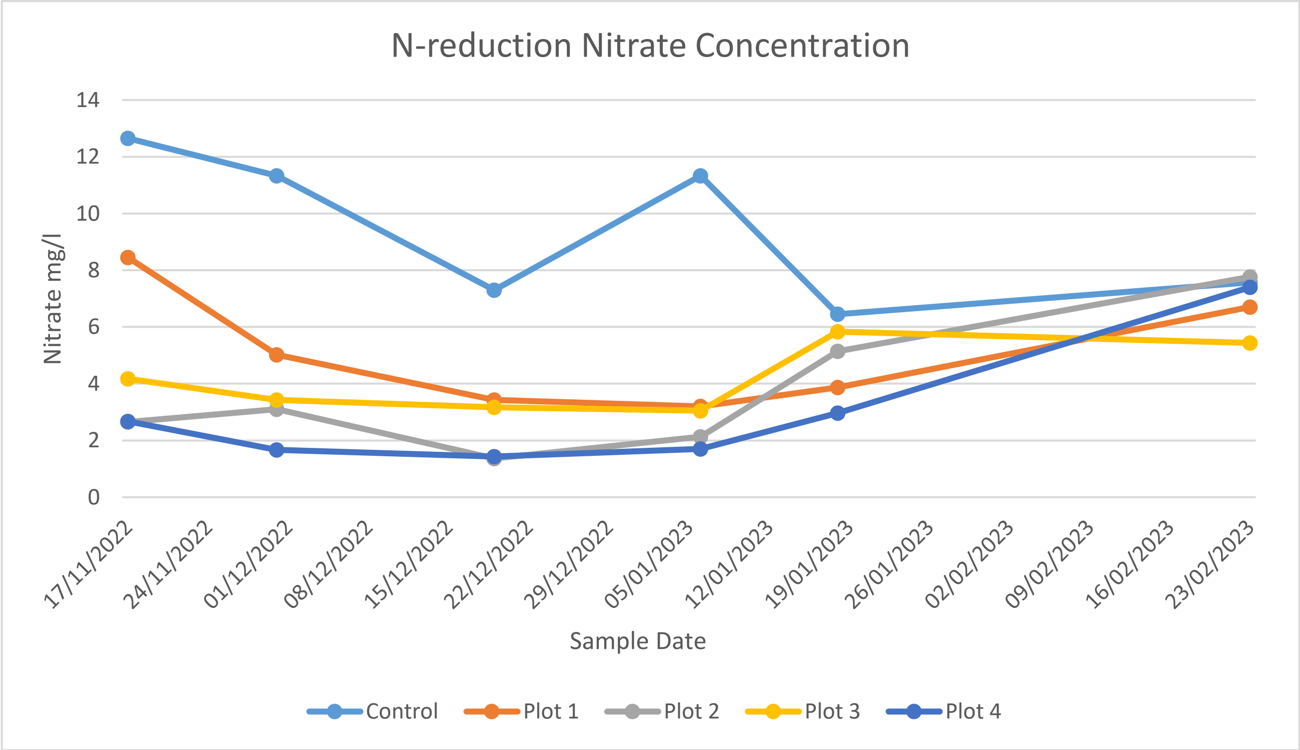


Figure 3. Porous pot results 2022-2023

Results Summary Year 2020:

Plot number	Control	1	2	3	4
Treatment (% reduction N)	0% (control)	5%	10%	15%	20%
Total N applied (kg N/ha)	280	266	252	238	224
Nitrogen use efficiency* (%)	47	49	52.3	52.05	56.25
Yield (t/ha)	13.2	13.02	13.18	12.39	12.6
Protein Content (%)	10.82	11.23	11.17	11.02	11.58
Gross margin incl fert costs** (£/ha)	£2,067	£2,045	£2,081	£1,956	£2,000
Difference between spring & autumn SMN results (kg available N/ha)	7.3	8.7	2.7	-7.6	-11.5

Nitrogen use efficiency = kg grain/ha divided by kg N applied/ha

***** Based on grain price of £170/t and market fertiliser price***

Results Summary Year 2021:

Plot number	Control	1	2	3	4
Treatment (% reduction N)	0% (control)	5%	10%	15%	20%
Total N applied (kg N/ha)	280	266	252	238	224
Nitrogen use efficiency* (%)	35	37.4	38	41.2	42.4
Yield (t/ha)	9.8	9.97	9.6	9.82	9.5
Protein Content (%)	12.88	12.21	11.48	11.26	10.77
Gross margin incl fert costs** (£/ha)	£1,767	£1,811	£1,746	£1,800	£1,745
Difference between spring & autumn SMN results (kg available N/ha)	48.9	30.2	25	-2	30.9

Nitrogen use efficiency = kg grain/ha divided by kg N applied/ha

***** Based on grain price of £200/t and market fertiliser price***

Results Summary Year 2022:

Plot number	Control	1	2	3	4
Treatment (% reduction N)	0% (control)	5%	10%	15%	20%
Total N applied (kg N/ha)	257	244	231	218	205
Nitrogen use efficiency* (%)	44	47	48	53	55
Yield (t/ha)	11.46	11.45	44.13	11.54	11.3
Protein Content (%)	13.45	12.84	13.22	12.3	11.63
Gross margin incl fert costs** (£/ha)	£2,469	£2,550	£2,462	£2,551	£2,479
Difference between spring & autumn SMN results (kg available N/ha)	42.6	32.2	44.3	28.2	37.1

Nitrogen use efficiency = kg grain/ha divided by kg N applied/ha

***** Based on grain price of £300/t and market fertiliser price***

Conclusions:

Reducing nitrogen applications in wheat has rightfully always been a controversial topic with growers and agronomists. The past three years have allowed us to put this to the test, exploring wheat's reaction to reduced inputs of artificial nitrogen in terms of yield and ultimately protein levels within the grain. Improving our understanding of how a plant reacts to reduce levels of nitrogen provides valuable information for both the agronomist and grower, allowing an easily visible consequence in terms of yield, protein and ultimately the financial return. With fertiliser prices in 2022 hitting a record high, weighing up the risk of applying large quantities of N on a wheat crop have never had so much focus.

The data gathered over the past three years has demonstrated the potential yield reduction because of cutting back nitrogen applications. Although it is worth noting that this reaction has not been anything like as drastic as I had expected. On average the yield reduction with a 20% nitrogen cut has been 0.38t/ha, with the biggest drop in 2020 (the highest yielding year). A similar trend has been seen with protein levels within the grain. A steady decline directly related to the reduced nitrogen application levels. 1% protein with a 20% N reduction (56kgN/ha).

In financial terms, when protein bonus is not considered (this is on appropriate in (control plot 2021, control 2022 & plot 2 2022)), the differences in terms of gross margin once the nitrogen price has been considered is not as drastic as one would expect. The differences between the most profitable plot and least in 2020 was £111, 2021 £66 & in 2022 £89. On average the most profitable plot over the three-year trial has been the 5% N reduction, followed by 15%, narrowly more profitable than the control. A useful observation when discussing nitrogen application rates with growers. If protein is considered, then there is of course quite a big difference, but the problem of chasing the higher protein is it is never a guaranteed premium.

This trial has also set out to improve our understanding of the relationship between reduced nitrogen applications on a crop of wheat and the consequence in terms of nitrate leaching through the soil profile. This has been measured using soil mineral nitrogen samples and over wintered porous pots installed in September and monitored through until February. The SMN data proves to be inconclusive in pinpointing a direct relationship between N applied and residual N after harvest.

However, the porous pot data clearly shows an elevated nitrate concentration within the soil profile following the higher N applications. This has been witnessed in all three years, with the control plots having the highest nitrate concentrations, followed by plot 1 (5% reduction). This links nicely with the nitrogen use efficiency of the crop.

Any questions then please contact Stephen Woodley (stephen@swoodleycropservices.co.uk)