Living Mulch Trial: Home Farm Climping

Independent Agronomy Services

Objective:

A trial was set up to assess if nitrogen inputs can be reduced where a clover understory was established prior to a wheat crop.
The trial assessed reduced nitrogen rates where a clover understory was established to determine the impacts on yield and grain quality, as well as full financial implications for the farm.

Assessments:

Soil mineral nitrogen (SMN) tests were taken in the autumn of 2022 prior to drilling, as well as early spring 2023, before any nitrogen inputs. The Yara N Tester was used mid season to determine the implications on chlorophyll content of the crop, followed by leaf tissue analysis as well as a full grain nutrient analysis and an SMN test post harvest to determine residual nitrogen levels following the crop.

Porous pots were established in the autumn of 23 to monitor the amount of nitrogen leached from each treatment over the winter.

Trial:

A clover understory was established mid august following a crop of peas before establishing the crop of winter wheat. The trial consisted of 4 treatments, a control treatment of field standard application, followed by treatment one, clover understory and a full nitrogen programme, treatment two a clover understory and a 10% reduction and treatment 3, a clover understory and a 20% reduction of the total N programme. The clover was treated with a herbicide late April to get the clover to release the nitrogen from the nodules to become available to the wheat crop.
Yield, leaf tissue tests, grain nutrient analysis and crop chlorophyll content were all measured through the growing season.

Trial Protocol:

Plot	Treatment	Protocol	Seed Rate	Fertiliser rate	
1	Control	No Clover	N/A	100%	Tramline 1
2	Treatment 1	Clover understory only	2kg/ha	100%	Tramline 2
3	Treatment 3	Clover Understory + N Reduction (10%)	2kg/ha	90%	Tramline 3
4	Treatment 4	Clover Understory + N Reduction (20%)	2kg/ha	80%	Tramline 4

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Site Location:

The site was in the south of England at Climping. Soil type is a Silty Clay Loam.

Figure 1 trials layout

Fertiliser Programme:

Treatment 1 - Tramline 1

Application	Product	Rate/ha	N
Sulphur	PotashPlus	217	0
N1	N37	135	50
N2	AN	290	100
N3	N37	270	100
N4	AN	116	40
			290

Treatment 2 - Tramline 2

Application	Product	Rate/ha	N
Sulphur	PotashPlus	217	0
N1	N37	135	50
N2	AN	290	100
N3	N37	270	100
N4	AN	116	40
			290

Treatment 3 - Tramline 3

Application	Product	Rate/ha	N
Sulphur	PotashPlus	217	0
N1	N37	135	50
N2	AN	290	100
N3	N37	270	71
N4	AN	116	40
			261

Treatment 4 - Tramline 4

Application	Product	Rate/ha	N
Sulphur	PotashPlus	217	0
N1	N37	135	50
N2	AN	290	100
N3	N37	270	42
N4	AN	116	40
			232

Growing Season and monitoring:

Establishment:

The clover was established mid-august by broadcasting onto a cultivated field and rolled following a crop of peas. The clover established well despite the dry conditions at the time. The clover was established at 2kg/ha using a small white leaf clover for its prostate growth and to ensure the clover didn't become too competitive against the wheat.

Prior to drilling the wheat, glyphosate (540g/ha) was applied due to wild oats and broad leaf weed presence. Despite being knocked the clover survived this.

The wheat was established by direct drilling into directly into the clover ley on the 8th October. This led to minimum damage to the clover as well as a well-established wheat crop. A pre emergence herbicide was applied shortly after drilling which led to a slight distortion of the clover but it grew through this.

Picture 1 clover established into cultivated ground.

Picture 2 wheat established into clover ley following glyphosate application.

Growing Season:

The clover came through the winter well with a good plant population. An early application of nitrogen to the wheat late February allowed the wheat to get away from the clover before any competition from the clover. By GS32 (late April) the clover started to grow more aggressively and become competitive against the wheat. A herbicide (Ally Max + CMPP) was applied to prevent competition from the clover impacting the yield of the wheat as well as aiming to release the nitrogen that had been fixed from the clover. Three to four weeks after application a leaf tissue test and the crop chlorophyll content where measured to allow sufficient time for any nitrogen uptake.

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Picture 3 clover growing prostate alongside the wheat giving greater ground cover

Picture 4 clover starting to extend and become more competitive against the wheat

Picture 5 clover roots nodulating showing evidence of nitrogen fixation

Picture 6 clover post herbicide application twisted up and allowing the crop to get away from any competition for space and light.

Results:

Soil Sample Results

Field Name	Soil Type	Analysis Date	PH	P (Index)	K (Index)	Mg (Index)
BLACKHORSE						
	Medium	21/10/2021	6.8	25 (2)	190 (2+)	45 (1)

As can be seen the field was at optimum pH as well as target index for phosphate and potash.

SMN Results

SMN levels were measured in at three different timings. September 2022, prior to drilling the wheat. February 2023, prior to applying any fertiliser, and September 2023 post-harvest. As can be seen SMN levels after the crop of peas were very high prior to drilling the wheat, however a lot of this was leached over the winter into 2023 due to high levels of rain through the winter. Before any fertiliser was applied in the Spring there was only a 3kg N/ha difference between each plot before any fertiliser applications. Post harvest however a clear difference can be seen between each plot, with more residual nitrogen left behind Treatment 1. Surprisingly, treatment 2 which had the full nitrogen application and clover had a reduced SMN compared to treatment 1. However, treatment 3 and 4 noticeably had a reduced SMN, with very little difference where a 10% reduction had been made compared to a 20% reduction.

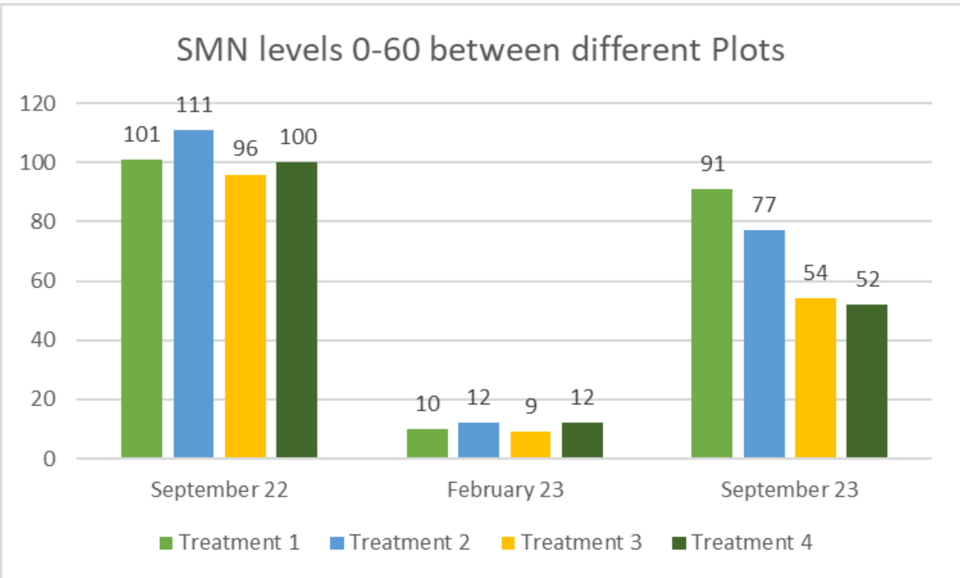

Figure 2 SMN results by plot taken over three timings across the growing season.

Leaf Tissue Test Results

Leaf Tissue test results were taken around the mid-May, 2-3 weeks after the clover was terminated to measure the nutrient analysis of the flag leaf. As can be seen across all plots Sulphur, Potassium, Zinc and Copper were deficient. All other elements where satisfied for the growth of the crop. Compost was applied in the spring of 22 as well as Polysulphate in the Spring of 23. It is therefore surprising to see Potassium and Sulphur coming up deficient. This may have been down to rapid growth at the time of sampling and a transient effect being seen.

	Units	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Nitrogen	%	4.15	4.14	4.12	4.04
Sulphur	%	0.295	0.302	0.289	0.269
Phosphorous	%	0.405	0.397	0.41	0.396
Potassium	%	2.55	2.34	2.31	2.21
Calcium	%	0.425	0.465	0.46	0.436
Magnesium	%	0.153	0.155	0.154	0.148
Manganese	mg/kg	45.5	49.7	47.6	46.6
Iron	mg/kg	92.7	89.5	82.6	79
Copper	mg/kg	4.28	4.31	4.56	4.21
Zinc	mg/kg	23.2	22.1	23.1	22
Boron	mg/kg	4.54	4.67	5.26	5.41

(pink)	Indicates a nutrient deficiency
(green)	Indicates nutrient requirement satisifed

Figure 3 trace element leaf tissue tests across each treatment

There is very little difference between Treatment1, 2, and 3 for nitrogen in the leaf. This indicates that the 10% reduction in application of bagged nitrogen is largely being satisfied by the clover. We do however see a significant drop off in leaf tissue nitrogen levels in treatment 4 where a 20% N reduction was made. This indicates that the clover may have been providing somewhere between 20-30kg N/ha to the crop at this time.

Yara N Tester Results

The Yara N tester was used on the flag leaf in late May to determine the chlorophyll content of the flag leaf between each treatment, as well as getting a nitrogen recommendation to satisfy yield and protein. The N tester gives a nitrogen recommendation by taking a predicted yield, the amount of N applied, the SNS index and the measured chlorophyll content of 30 plants across the field. Surprisingly the chlorophyll content increased where the clover understory was used compared to the control treatment (Treatment 1). With a predicted yield of 12.5T/ha and aiming for milling wheat spec the N tester gives a recommendation for a total additional recommendation to achieve spec.

Interestingly where the crop had a clover understory there was a slightly lower total N recommendation then where only bagged fertiliser was used. Where a 20% reduction in N was made, the total recommended nitrogen requirement would have been 20kgN/ha lower. Treatment 4, where a 20% reduction in N was made had the highest average N tester value (chlorophyl content), potentially due to the clover fixing more nitrogen due to less bagged nitrogen being available. These results however didn't correlate with the nitrogen in the leaf tissue tests taken a fortnight before.

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Average N Tester Value	**680**	**705**	**691**	**725**
Yara N recommendation (kg N/ha)	22	20	46	60
N application to date	290	290	261	232
Yara Total N recommendation	312	310	307	292

Figure 4 Yara N tester results across each treatment

Grain Nutrient Analysis

Despite some of the leaf tissue tests coming back showing deficiencies, the grain nutrient analysis tells us that come harvest there were no deficiencies present. However, both treatment 1 and treatment 3 had a slightly high N:S ratio, supporting the tissue analysis that sulphur may have been slightly under applied. This is likely to be due to the excessive rain through the spring leading to some of the sulphur leaching through the season. Interestingly phosphate, potash and magnesium levels were all slightly higher where the clover was present, although this is unlikely to be significant.

Element	Unit	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Nitrogen	%	2.32	2.3	2.37	2.15
Grain Protein	%	13.224	13.11	13.509	12.255
Phosphorous	%	0.345	0.378	0.392	0.367
Potassium	%	0.499	0.535	0.541	0.51
Sulphur	%	0.13	0.14	0.13	0.13
Magnesium	%	0.109	0.116	0.118	0.112
N:S Ratio		17.8:1	16.4:1	18.2:1	16.5:1
Copper	mg/kg	2.79	2.88	2.98	3
Manganese	mg/kg	26.4	27.2	27.6	25.44
Zinc	mg/kg	20.3	19.4	18.6	17

Figure 5 grain nutrient analysis across each treatment at harvest.

Treatment 1,2,3 all hit full spec milling wheat protein target of 13%, however treatment 4, where there was a 20% reduction in nitrogen saw the protein levels drop off quite quickly. This would have still achieved a premium for milling quality but with quite a significant financial penalty of £2.50/percentage point dropped.

Yield:

As can be seen Treatment 1 (field standard) gave the highest yield, followed by Treatment two (Field standard + clover). There was no significant difference between either the yield or protein between treatment one or two, but there was a small significant difference in yield where a 10% and 20% reduction in N had been made. Where a 10% reduction in nitrogen had been made, protein levels where actually higher, however this was not significantly different from Treatment 1 or 2. Treatment 4 however, had a significantly lower protein level, and dropped the crop below the full spec 13% milling wheat standard. This means it is likely to have had a significant financial impact on the gross margins where premiums of £60/t could be achieved. It is therefore likely that nitrogen was not a limiting factor on the field standard applications. But a slight drop in yield for treatment 3 and 4, followed by a significant drop in protein for treatment 4 would imply that the crop was beginning to fall back down the N response curve where nitrogen was being reduced passed 10%.

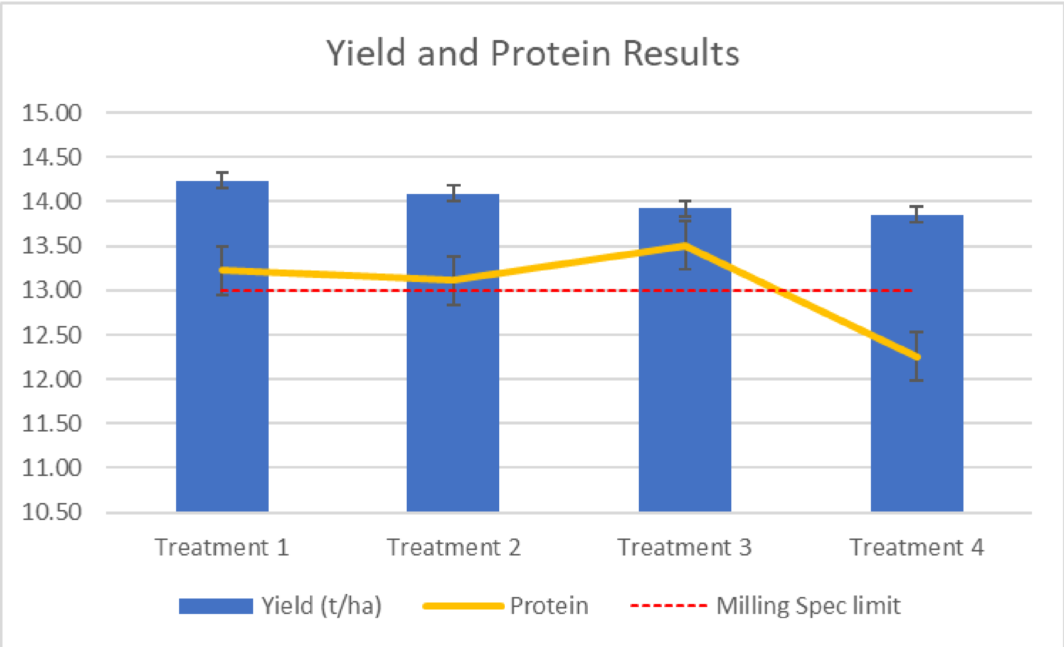

Figure 6 yield and protein results across each treatment.

Nitrogen use efficiency was then calculated to show differences between treatment. On the whole the NUE was high, showing a good uptake of Nitrogen across the field. Treatment 3 however gave the highest NUE, where NUE is very high this indicates that nitrogen was mined from the soil or potentially fixed through the clover during the growing season. Treatment 4 sees a significant drop in NUE however where grain N levels begin to drop.

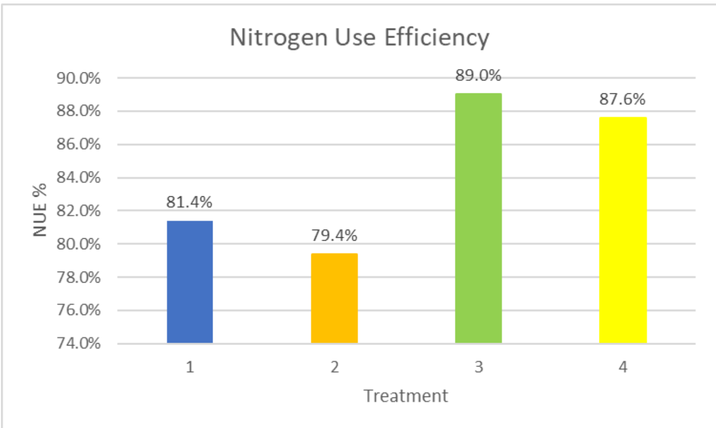

Figure 7 nitrogen use efficiency across each treatment

Financial Implications

Where milling wheat was achieved a premium of £60/t could be expected, however a drop in protein below this saw a penalty of £2.50/percentage point. With a base wheat feed price of £190/t any drop below 12% spec would have led to a significant financial implication. Treatment 4 still made 12.2% protein, and therefore was still marketable as a low spec milling wheat with a £20/t penalty. This meant that full spec milling wheat had a sales price of £250/t, whilst the low spec wheat would have made £230/t.

The clover cost approx. £15/ha in seed, an allowance of £60/ha has been used for the cost of establishment, however this may vary on farm depending on drill and establishment type. Broadcasting or direct drilling will be significantly cheaper than a cultivation or a combi drill which would reduce the input costs.

As can be seen there is only a £103/ha difference between treatment 1 and treatment 3 despite a 10% reduction in fertiliser application. Treatment 2 has a lower gross margin then 3 due to the additional establishment cost and no improvement in yield. It is therefore only worth growing a clover understory from a financial reason if a nitrogen reduction is to be made. Where a 20% reduction in Nitrogen has been made there is a significant financial implication due to a drop in yield and sales price.

Input Costs	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Clover Seed £/ha	0	15	15	15
Clover Establishment £/ha	0	60	60	60
Fertiliser £/ha (N only)	522	522	469	417
Total	522	597	544	492
Output				
Yield t/ha	14.24	14.09	13.92	13.85
Milling Spec	Full Spec	Full Spec	Full Spec	Low spec only
Sales Price £/t	250	250	250	230
Total Output	3561	3521	3480	3186
***Gross Margin £/ha**	**3039**	**2924**	**2936**	**2694**
*Gross margin before, seed, Plant protection products, Compound fertilisers and opporational costs				

Figure 8 gross margins from each treatment

Although nitrogen rates would be significantly different for feed wheats and milling wheats, if a feed wheat was grown on the current programme and marketable crop was all sold at a base price of £190/t, the gross margins begin to look very different. Treatment 1 would still give the highest margin, however treatment 4 which had a 20% reduction in N, would only be £44/ha lower in gross margin, with a much lower investment, a smaller carbon footprint as well as leaving less nitrogen to be leached after the crop. It therefore begins to look much more appealing for those growers growing a feed crop where grain protein levels are not as important.

Input Costs	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Clover Seed £/ha	0	15	15	15
Clover Establishment £/ha	0	60	60	60
Fertiliser £/ha (N only)	522	522	469	417
Total	522	597	544	492
Output				
Yield t/ha	14.24	14.09	13.92	13.85
Milling Spec	N	N	N	N
Sales Price £/t	190	190	190	190
Total Output	2706	2676	2645	2632
*Gross Margin £/ha	**2184**	**2079**	**2101**	**2140**
*Gross margin before, seed, Plant protection products, Compound fertilisers and opporational costs				

Figure 9 gross margin implications if only grown to a feed wheat specification.

Discussion

Where growing a milling wheat, it is essential to get grain protein to hit the premium markets. Therefore, nitrogen isn't likely to be a limiting factor for yield but could be for protein. There is however a drive to reduce nitrogen inputs on farm as well as grow crops with an increased environmental conscience. Finding alternative nitrogen sources or ultimately improving NUE is a key driver on farm without reducing gross margins. As can be seen it is likely that a living mulch can help supply some of the nitrogen to the crop and replace bagged fertiliser. If taking the figures from this field trial it could be estimated that the clover fixed around 20-30kgN/ha throughout the growing season given that the 10% reduction only saw a minor reduction of yield, but an increase in grain N and NUE.

There are also many additional benefits from growing a living mulch such as greater protection of the soil due to more cover, reduction of synthetic nitrogen, a reduction in greenhouse gas emissions, improved soil structure, as well as a significant opportunity to reduce the amount of nitrogen leached after the wheat crop. The ability to terminate the clover in late April also gives the chance to get nitrogen in the soil at times when droughts are becoming more common. If the clover can be knocked but kept alive, there is also an opportunity to graze with livestock after harvest. With the additional option of companion cropping under the new SFI options, companion crops could also add a further £55/ha onto the gross margin of this situation.

However, it does come with its challenges. Establishment needs to be early summer or even in the spring to allow the clover to be well established at the time of drilling the wheat. Glyphosate will ultimately kill clover; however it will survive a low rate. Unfortunately, so will many other weeds, and cutting back rates where problem weeds are present may lead to glyphosate resistance so must be treated with care. The clover also ultimately needs to be damaged or destroyed to get the root nodules to release nitrogen for the growing crop, if wanting to keep the clover alive for 2-3 years this may prove challenging to get right without letting the clover compete against the wheat.

There are also rotational constraints to think about. White clover hosts many of the foot rot pathogens that can also be found in peas and beans, so if using on farm it is important to make sure the rotation is extended to allow for a decrease in any pathogens prior to re planting a cash crop.

Clover has the potential to host pests for other cash crops such as Pea aphids (Acyrthosiphon Pisum), which can then infect the peas in the neighbouring field. On this farm the pea aphid pressure was the highest we have ever seen, and this may be as a result of the clover hosting the species over winter.

When reviewing other trial work done elsewhere, competition is one of the biggest challenges to ensuring the clover is beneficial and not a hindrance. It is therefore essential that the wheat variety chosen is vigorous in its spring growth to out compete the clover, varieties like KWS Extase are perfect in this scenario. Using a small leaf clover, that grows prostrate, rather than upright will allow the wheat to outcompete the clover too. Spraying the clover at the correct time is also essential to ensure nitrogen is fixed but that the clover does not out compete the wheat causing a yield decline.

It is worth noting that these trials were not replicated and are only as accurate as the gps mapping of the plots as well as the weighbridge. Further replications on a field scale and ideally of small plot trials would likely to be needed to estimate more accurately what could be fixed in a growing year as well as having a greater range of nitrogen responses.

Conclusion

There are potentially many benefits to having a living mulch such as nitrogen fixation, increased biodiversity, and the opportunity to reduce inputs. Overall, it is difficult to definitively say how much nitrogen is released in a growing season by growing wheat with a living mulch. This will vary depending on the number of plants per m2, vigour of the clover and the nodulation in the spring. This will ultimately have to be assessed on a field-by-field basis. We can see where a 10% reduction in nitrogen was made, grain yield was only slightly reduced, however protein was increased, likely from a late release of nitrogen when terminating the clover. This saw an increase in NUE suggesting there was a reasonable level of nitrogen fixed from the clover. However, where a 20% reduction in nitrogen was made the yield, protein and NUE all began to drop. Therefore, if growing a wheat with a living mulch a reduction of 20-30kg/N/ha may be achievable providing a good establishment of clover.