Living Mulch Trial: Manor Farm Lavant

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.

Trial:

A clover understory was established in late august following a crop of spring oats 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 in mid-march to get the clover to release the nitrogen from the nodules to become available to the wheat crop. This was earlier then preferred but grassweed pressure in the field meant earlier control was required.
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

Site Location:

The site was located in the south of England near Lavant on a Silty Loam soil over chalk.

Figure 1 trials layout

Fertiliser Programme:

Treatment 1 - Tramline 1 - Field Standard

Application	Product	Rate/ha	N
N+S	N19 + 19SO3	263	50
N1	AN	290	100
N2	AN	232	80
			230

Treatment 2 - Tramline 2 - Field Standard + Clover

Application	Product	Rate/ha	N
N+S	N19 + 19SO3	263	50
N1	AN	290	100
N2	AN	232	80
			230

Treatment 3 - Tramline 3 - 10% N reduction + Clover

Application	Product	Rate/ha	N
N+S	N19 + 19SO3	263	50
N1	AN	290	100
N2	AN	232	57
			207

Treatment 4 - Tramline 4 -20% N reduction + Clover

Application	Product	Rate/ha	N
N+S	N19 + 19SO3	263	50
N1	AN	290	100
N2	AN	232	34
			184

Growing Season update:

Establishment:

The clover was established late august with a John Deere 750A direct drill into a lightly cultivated field and rolled after Spring Oats. Due to the lack of moisture at the time of drilling the clover establishment was very slow and poor. Establishment was variable across the field. When it did rain, spring oat volunteers led to early competition so had to be removed with a graminicide.

Prior to drilling the wheat glyphosate (540g/ha) was applied due to the presence of grass weeds and broad leaf weeds. Despite being knocked the majority of the clover survived this.

The wheat was established by direct drilling into directly into the clover ley early 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. However, as the clover was still small at the time of drilling, some of the clover was more severely damaged.

Picture 1 clover establishing with weed pressure from volunteer spring oats and other broadleaf weeds

Picture 2 wheat direct drilled into the clover ley, the roundup and pre emergence herbicide application has knocked the small clover plants

The clover came through the winter without putting on much growth and a low plant population. Frosts in January led to surface frost heave with damaged the rooting of small plants and led to a further thinned out plant population. Unfortunately, due to the grass weed pressure of brome in the wheat field, an application of an SU herbicide late in March was applied (0.5l/ha Pacifica Plus). This unfortunately knocked and ultimately killed the clover which meant the clover had less chance to nodulate and fix nitrogen in the spring.

Picture 3 clover struggling to get going, frosts in January further thinning out the plant population

Results

Soil Sample Results

Field Name	Soil Type	Analysis Date	PH	P (Index)	K (Index)	Mg (Index)
Hayes Barn						
	Medium	05/10/2022	8.0	18 (2)	249 (3)	62 (2)

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 Spring Oats were very variable prior to drilling the wheat with two plots very high, and two plots at a much lower level. This could be due to Farm yard manure being applied earlier in the spring skewing results. 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 7kg 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 and 2, with the reduced N plots of 3 and 4 having a lot lower nitrogen levels. There was very little difference in SMN results where 10 and 20% N reductions were made.

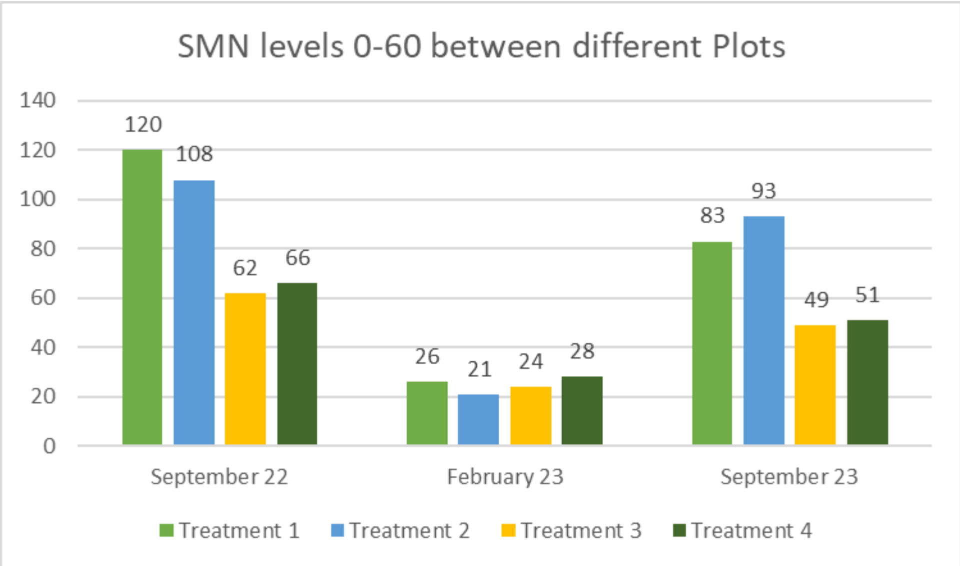

Figure 2 SMN results by plot taken over three timings across the growing season.

Leaf Tissue Tests

Leaf Tissue test results were taken around the mid-May to measure the nutrient analysis of the flag leaf. As can be seen across all plots Sulphur, Potassium, Zinc and Copper were deficient, and treatment 2 and 3 also had Magnesium levels dropping low whilst treatment 1 and 2 showed Boron levels low. All other elements were satisfied for the growth of the crop. Farm yard manure was applied in the spring of 22 and 50kg SO3 was applied in the spring of 2023. 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	%	3.83	3.74	3.77	3.69
Sulphur	%	0.256	0.241	0.233	0.252
Phosphorous	%	0.351	0.331	0.317	0.368
Potassium	%	2.55	2.49	2.4	2.25
Calcium	%	0.375	0.377	0.338	0.346
Magnesium	%	0.13	0.125	0.114	0.134
Manganese	mg/kg	72.2	65.3	60.3	78.7
Iron	mg/kg	70.9	70.6	69.8	77.1
Copper	mg/kg	4.51	5.09	4.75	4.34
Zinc	mg/kg	25.1	25.9	24.2	24.8
Boron	mg/kg	3.85	3.48	8.13	7.21

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

Figure 3 trace element leaf tissue tests across each treatment

There is reduced nitrogen in the leaf where N reductions took place, with treatment 3 and 4 showing less nitrogen in the leaf compared to treatment one. However, there is very little difference between treatment 2 and 3, implying that the clover is not fixing much nitrogen to supplement the 10% reduction. This is likely to be due to the low plant count and early termination of the clover. On the whole there is very little difference between all treatments, with nitrogen levels being satisfied across each plot.

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.

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Average N Tester Value	**641**	**687**	**630**	**663**
Yara N recommendation (kg N/ha)	65	37	100	92
N application to date	230	230	207	184
Yara Total N recommendation	295	267	307	276

Figure 4 Yara N tester results across each treatment.

The chlorophyll content across each treatment varied. However interestingly Treatment 2 and Treatment 4 had the higher chlorophyll content. This could have been to nitrogen being released through the clover. Treatment 2, the field standard + Clover had the lowest recommended N to apply, which implies that the clover had fixed a level of nitrogen on top of the bagged fertiliser applications. Due to the variability across treatments however it is hard to draw any clear conclusions.

Grain Nutrient Analysis

Despite some of the leaf tissue tests coming back showing deficiencies in Sulphur, Potassium, and Zinc, at harvest these were not evident implying the deficiencies were likely transient. However, all treatments had a low phosphate level despite the leaf tissue test implying there were no deficiencies. Whilst nitrogen levels were not deficient enough to impact the yield of the crop, the grain protein levels dropped below the milling wheat market requirement of 13%. Treatment 2 and 3 were above 12%, so would have satisfied a low protein market, however Treatment 4, would have only made feed wheat with grain protein levels too low. This would have led to a significant reduction in sales price.

Element	Unit	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Nitrogen	%	2.3	2.15	2.18	2.06
Grain Protein	%	13.11	12.255	12.426	11.742
Phosphorous	%	0.295	0.292	0.295	0.297
Potassium	%	0.478	0.48	0.484	0.485
Sulphur	%	0.14	0.13	0.13	0.13
Magnesium	%	0.097	0.101	0.1	0.1
N:S Ratio		16.4:1	16.5:1	16.8:1	15.8:1
Copper	mg/kg	3.91	3.62	3.82	3.76
Manganese	mg/kg	40.3	36.8	29.7	38.9
Zinc	mg/kg	26.2	27.4	26	25.9

Figure 5 grain nutrient analysis across each treatment at harvest.

Yield:

As can be seen Treatment 1 (field standard) gave the highest yield and protein, followed by Treatment two (Field standard + clover), with significant yield reductions for treatment 3 and 4 where 10% and 20% nitrogen reductions were made. All treatments with clover fell short on protein, including treatment 2 which had a full fertiliser rate as well. This would imply that not enough nitrogen was applied to the crop in treatment 3 and 4 at a base level to satisfy yield let alone protein. Treatment 4 showed a significant drop in protein, failing to even meet the low spec milling wheat standard of 12%. This means it is likely to have had a significant financial impact on the gross margins where premiums of £60/t could be achieved. Treatment 1 reached 13% protein, however treatment 2 was lower didn't despite a lower yield. With field variability it is therefore likely that nitrogen was a limiting factor on protein where the field standard application was made. Treatment 3 and 4 with reduced N applications show that even 10% reduction in N led to a significant yield decline as well as protein reduction, implying very little nitrogen was fixed from the clover.

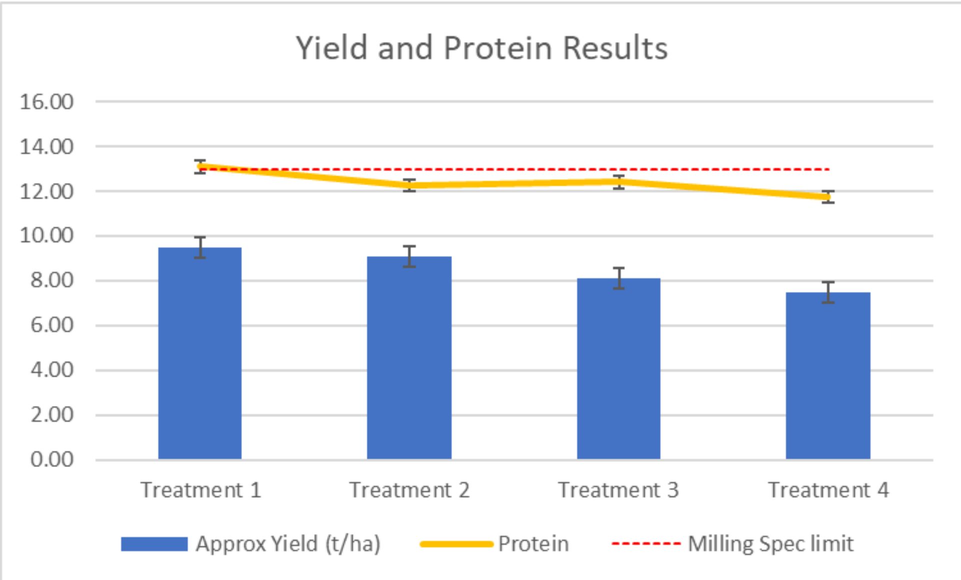

Figure 6 yield and protein results across each treatment.

Nitrogen use efficiency (NUE) was then calculated to show differences between treatment. On the whole the NUE was about average for treatment 1, but low in the others, showing that yields and protein levels could have been higher. This is likely to be as a result of poor sunlight levels and excessive rainfall throughout 2022 and 2023. The field standard gave the highest NUE, showing no response or increase in NUE where clover was used as a living understory.

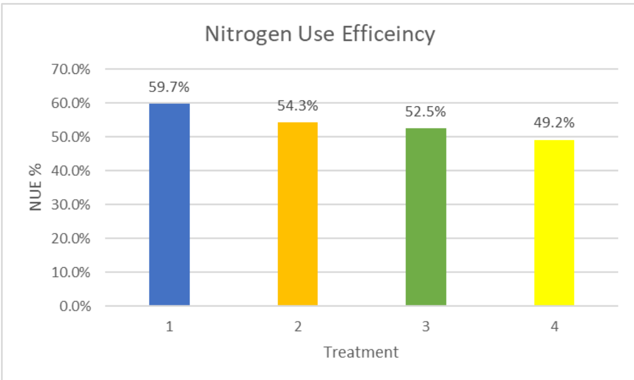

Figure 7 nitrogen use efficiency across treatments

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 2 and 3 still made 12.2 and 12.4% protein, and therefore was still marketable as a low spec milling wheat with a £20/t and £15/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 and £235/t respectively. Treatment 4 would have failed to demand any premium with protein levels too low so was only sold as feed.

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. Direct drilling is a relatively cheap way to establish clover.

As can be seen there is a significant difference between all treatments in gross margin predominantly due to the combination of yield reduction and loss of premium from a drop in protein. The farm standard had the highest gross margin by over £350/ha with a reduced establishment cost and improved yield and protein. In this instance the addition of a clover understory did not fix any additional nitrogen, and this is most likely due to poor establishment and early termination. Therefore, reducing nitrogen levels in this instance was very detrimental to the financial outcome of the trial.

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)	500	500	453	402
Total	500	575	528	477
Output				
Yield t/ha	9.50	9.10	8.10	7.50
Milling Spec	Full Spec	Low Spec	Low Spec	Feed Wheat
Sales Price £/t	250	230	235	190
Total Output	2375	2093	1904	1425
***Gross Margin £/ha**	**1875**	**1518**	**1376**	**948**
*Gross margin before, seed, Plant protection products, Compound fertilisers and opporational costs				

Figure 8 gross margin from each treatment

Although nitrogen rates would be 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 differences between treatment 2 and 3 become a lot closer where we had a 10% reduction in N. With the SFI payments for companion crops potentially giving another £55/ha then treatments 2,3 and 4 would all have an additional £55/ha applied reducing the differences seen. With a significantly lower carbon footprint and reduced nitrogen applications and therefore less nitrogen to be leached throughout the season this may be appealing to some farms.

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)	500	500	453	402
Total	500	575	528	477
Output				
Yield t/ha	9.50	9.10	8.10	7.50
Milling Spec	Feed	Feed	Feed	Feed
Sales Price £/t	190	190	190	190
Total Output	1805	1729	1539	1425
***Gross Margin £/ha**	**1305**	**1154**	**1011**	**948**
*Gross margin before, seed, Plant protection products, Compound fertilisers and opporational costs				

Figure 9 gross margin report if only grown for a feed wheat specification

Ultimately yield and protein are still king when it comes to growing wheats, and the reduction in yield in this instance is too high to counter the potential to reduce nitrogen levels. Had the clover been better established and taken through further in the year this may have been different.

Discussion

Where growing a milling wheat, it is essential to get grain protein to hit marketability. Therefore, cutting back nitrogen rates can lead to a significant reduction in protein and therefore gross margin. 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. In this instance having clover as an understory was unsuccessful in helping to replace bagged fertiliser as a form of nitrogen to feed the crop. This is most likely to be linked to the fact that the establishment was poor, with a low plant population of clover and due to grass weed pressure, an early herbicide had to be applied, taking out the clover before it could fix any significant nitrogen.

Despite being unsuccessful in replacing bagged nitrogen with nitrogen from the clover source a lot can still be taken from this trial. Establishing the clover as early as possible is key to getting a good plant stand. Where harvest is likely to be delayed, broadcasting into the standing crop may be an option to get the clover established well in advance of drilling the wheat crop. Due to the later planting and dry weather at drilling, the clover was small when the glyphosate and pre-emergence spray was applied, which reduced the vigour of the clover significantly. Due to the small size of the clover leading into the winter, the winter hardiness was reduced, with the frost then thinning the plants out even further. Having to then put an early herbicide on for control of grass weeds the clover had no real chance of fixing any nitrogen. It is therefore important to pick a site where early establishment of the clover is possible, and preferably a site free from grass weeds and broadleaf weeds where early herbicide control will be required.

There are potentially 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.

There are however 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.

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.

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. Being able to spray 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.

These trials were not replicated and are only as accurate as the gps mapping of the combine yield maps. No weighbridge data was taken so yields are only estimated off yield maps. Further replications on a field scale or in small plots 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, but ultimately like all crops, good establishment is key to success. Assessing establishment and root nodulation will be key to determine the ability of the clover to fix nitrogen. If the crop is not established well, then very little nitrogen is likely to be fixed and nitrogen rates are unlikely to be suitable to cut back. In this instance no yield or protein response was seen to the addition of clover, and when nitrogen rates were cut back both protein and yield dropped. Unsurprisingly where nitrogen rates were cut back, SMN levels after harvest were lower, reducing the risk of pollution to groundwater. However, reducing nitrogen and therefore reducing the yield and protein led to this giving a much lower gross margin on farm.