IMPROVING SOIL TO OPTIMISE WATER USE ON-FARM

KEY POINTS

- **The economic analysis showed there were a number of low and high-cost options for stubble retention which provide alternatives to burning.**
- **A high liming rate of 6.7t/ha was applied across the demonstration to address the acidity in the 5-15cm layer of soil.**
- **The liming increased the 0-10cm pH across all treatments increased to pH 5.8 or higher, which is the target level of pH to address subsurface acidity.**
- **The 10-20cm pH results for the unincorporated lime treatments were not consistent with current research and require further investigation.**

AIM

To demonstrate different methods to retain stubble for soil moisture retention.

METHOD

The demonstration treatments were decided in collaboration with local farmers and agronomists in the Murchison district of northern Victoria (Table 1). The cost of each treatment was measured using contract rates.

Table 1. Cost of stubble treatments in addition to farmers normal harvest costs (cost does not include liming).

TREATMENT	CALCULATION	DATE	COST $/HA^
1. Harvest cut high# bale 1.7t/ha straw	Income from straw $25 less cost of nutrient removal $62 (see Appendix 2)	20/1/2021	$37
2. Harvest cut low#	Additional cost of cutting low	17/12/2021	$123
3. Harvest cut high, deep incorporation* of stubble		17/02/2022	$125
4. Harvest cut low, deep incorporation of stubble	Additional cost of cutting low $123 deep incorporation $125	17/02/2022	$248
5. Harvest cut high, flail mulch stubble		24/01/2022	$45
6. Harvest cut high, shallow incorporation** of stubble		24/02/2022	$45
7. Harvest cut low, shallow incorporation** of stubble	Additional cost of cutting low $123 shallow Incorporation $45	24/02/2022	$168
8. Burn	Cost of nutrient removal $20 (see Appendix 3), estimated cost of labour for burning $35	06/04/2022	$55

#Harvest cut high: stubble is cut at 40cm, harvest rate is 2.2ha/hr; harvest cut low 15-20cm, harvest rate is 4.89ha/hr

*Deep incorporation was done using a Performer, which cuts, chops and incorporates stubble to a depth of about 15cm. All cultivated treatments required an additional pre-sowing weed spray compared to uncultivated and burned.

^Header contract rate $550/hr, header fuel rate 60L/hr, fuel cost $1.50/l

**Shallow incorporation was done using a multidisc, which chops and incorporates stubble just below the surface. All cultivated treatments required an additional pre sowing weed spray compared to uncultivated and burned.

^In addition to standard farmer practice of harvesting high.

The stubble treatments were done at or after harvest of a wheat paddock in 2021, which was then sown to a second wheat in 2022. A wheat-on-wheat rotation was chosen at Murchison East (Table 2), as traditionally, stubble is burned after the first wheat crop, in preparation for the second. Some of the treatments in the demonstration were based on a four-year research trial in the Riverine Plains which showed that stubble management play a significant role in overall crop production (Riverine Plains Inc, 2019).

Table 2. Site description

LOCATION	MURCHISON EAST
Rainfall (mm): Jan – March Rainfall (mm): April -October Rainfall (mm): Jan-December	88 490 679.5
Sowing date	**8 May 2021**
Row spacing	300 mm
Soil type	Clay
Organic carbon (% 0-10cm)	1.5
Colwell P (mg/kg 0-10cm)	60
Sulphur (KCL 40 0-10cm)	10

A previous project in the region shows that high producing cropping soils may have a layer of acidity below 10cm. Hence, part of the methodology of this project included taking segmented sampling in 5cm increments down to 20cm on the 19 January 2022. This was to identify acid layers and lime requirements. Deep nitrogen and soil moisture samples were also taken on 21 May 2022. Soil sampling for soil moisture, acidity and nitrogen was repeated in January 2023 to allow measurement of changes to the system.

Stubble treatments were applied at different dates between harvest of the wheat crop on 20 December 2021 and sowing of the 2022 Scepter wheat crop on 8 May 2022. Yields were collected using yield monitor data and two samples from each treatment were tested for grain quality and grain nutrient analysis. Grain samples and yield data in December 2022 were taken from the northern area of the paddock that was less affected by waterlogging.

RESULTS

Cost of stubble management treatments

The cost of stubble management treatments from the different stubble management options ranged from $37/ha to $245/ha (Table 2). The lower cost options were burning; baling straw after harvest; shallow incorporation of stubble (using a speed tiller) and flail mulching.

The medium cost options were harvest cut low; harvest cut high/deep incorporation and harvest cut low/shallow incorporation. The most expensive stubble management treatment was harvest cut low/deep incorporation.

The cost of the lime ($60/t) and surface application ($11/t) of 6.7t/ha was $475/ha. The best management practices to incorporate the lime into a wheat stubble is to cut it low and then mechanically incorporate to the required depth, which in this demonstration cost $248/ha.

Soil and water test results 2022

The soil test results showed that acidity was higher in the 10-20cm layer compared to the 0-10cm layer (Table 3). More intensive sampling at 5cm increments (data not shown) showed elevated aluminium levels at 5-10cm, 10-15cm and 15-20cm. Results from the sampling were used to determine a lime application rate of 6.7t/ha, which was applied across the whole demonstration site in May 2022.

Deep nitrogen sampling showed that the quantity of nitrogen after the stubble treatments were applied was varied in the top 20cm, with Treatment 4, deep incorporation with the highest amount of nitrogen (Table 3). There were also differences in Plant Available Water (PAW) between treatments. The 'cut short' treatment had the highest plant available water, followed by burning. The deep incorporation dried the profile out, especially below 20cm.

Table 3. pH (sampled 19 January 2022), Nitrogen and PAW measurements (sampled 8 May 2022).

TREATMENT	pHCaCl2 (0-10cm)	pHCaCl2 (10-20cm)	DEEP N KGN/HA 0-20CM	DEEP N KGN/HA 20-60CM	PAW (MM) 0-20CM	PAW (MM) 20-60CM	PAW (MM) 0-60CM	PAW (MM) 0-60CM
2. Harvest cut short	4.8	4.5	28.3	13.2	22.8	33.7	56.5	
3. Harvest cut long, deep incorporation of stubble	4.8	4.4						
4. Harvest cut low, deep incorporation of stubble			39.3	12.6	19.3	6.5	25.8	
7. Harvest cut low, shallow incorporation of stubble.	Additional cost of cutting low $123 deep incorporation $125	5.1	4.7					
8. Burn		5.9	4.6	34.1	9.5	12.5	32.7	45.2

Plant density, tiller counts dry matter and yield results

Plant densities and tiller counts varied between treatments (Table 4). By the time dry matter samples were taken on 5 September, most treatments had a similar amount of dry matter (between 5.4 and 6.1t/ha). One exception was Treatment 3, harvest cut high, deep incorporation, which had the highest dry matter of 6.8t/ha. The other outlier was the harvest cut low which had the lowest dry matter of 5.2t/ha.

The paddock yield and quality was extremely variable across the paddocks (ranging between 0.1t/ha and 8.6t/ha) and appeared to be more of a result of water logging rather than stubble treatment (Figure 1). There did not seem to be a correlation between dry matter production (at tillering) and final yield (yields presented in Table 4). In general the proteins were good across treatments and the reason some samples were downgraded to AGP 1 was mainly due to low test weights, which reflects that the plants were stressed and waterlogged at the critical times of flowering and grainfill. Grain nutrient testing showed varied nutrient removal levels depending on crop yield (Appendix 1).

Table 4. Plant counts, dry matter counts, head counts, final yield, protein, test weight and screenings.

TREATMENT	PLANT DENSITY (PLANTS/ M2)	TILLER COUNTS (TILLERS/ M2)	DRY MATTER (T/HA)	HEAD COUNT (HEADS/ M2)	YIELD* (T/HA)	PROTEIN %	GRADE
1. Harvest cut high# bale straw	110	343	6.0	315	5.1	11.2	AGP 1
2. Harvest cut low#	109	318	5.2	289	4.7	11.6	AUH 2 & AGP1
3. Harvest cut high, deep incorporation* of stubble	113	425	6.8	372	4.7	13.3	AGP1
4. Harvest cut low, deep incorporation of stubble	107	356	5.4	319	5.1	12.6	AUH2 & AGP1
5. Harvest cut high, flail mulch stubble	127	364	6.1	343	5.3	11.7	H2 & APW1
6. Harvest cut high, shallow incorporation** of stubble	106	334	5.7	300	5.4	13	AGP1
7. Harvest cut low, shallow incorporation** of stubble	122	357	5.8	334	5.8	11.5	APW1 & H2
8. Burn	109	292	5.5	294	6.0	11.6	AGP1 &H2

*Yields were calculated by Precision Ag using Whiteboxgeo to process yield data to remove high level of noise.

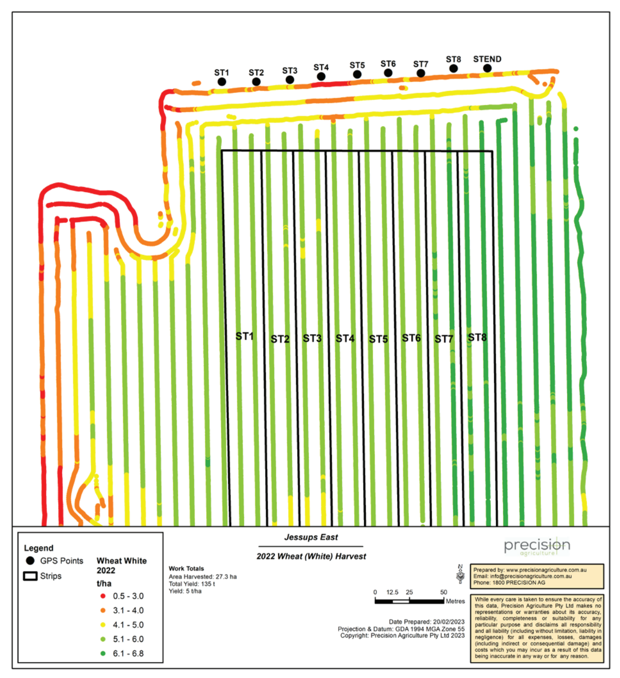

Figure 1. Yield map for stubble management demonstration

Post-harvest residual soil nitrogen and water results

Of the three treatments tested, post residual nitrogen levels were the highest in Treatment 4, deep incorporation, followed by Treatment 2 cut short (Figure 2). The higher levels of nitrogen and soil water in these treatments relate to lower grain yields in these treatments, causing less water and nutrient to be removed. The lowest residual nitrogen and soil water levels were in treatment 8 burn, which correlates to the higher grain yield in this treatment removing more water and nutrient (for grain nutrient removal figures per treatment, see Appendix 1).

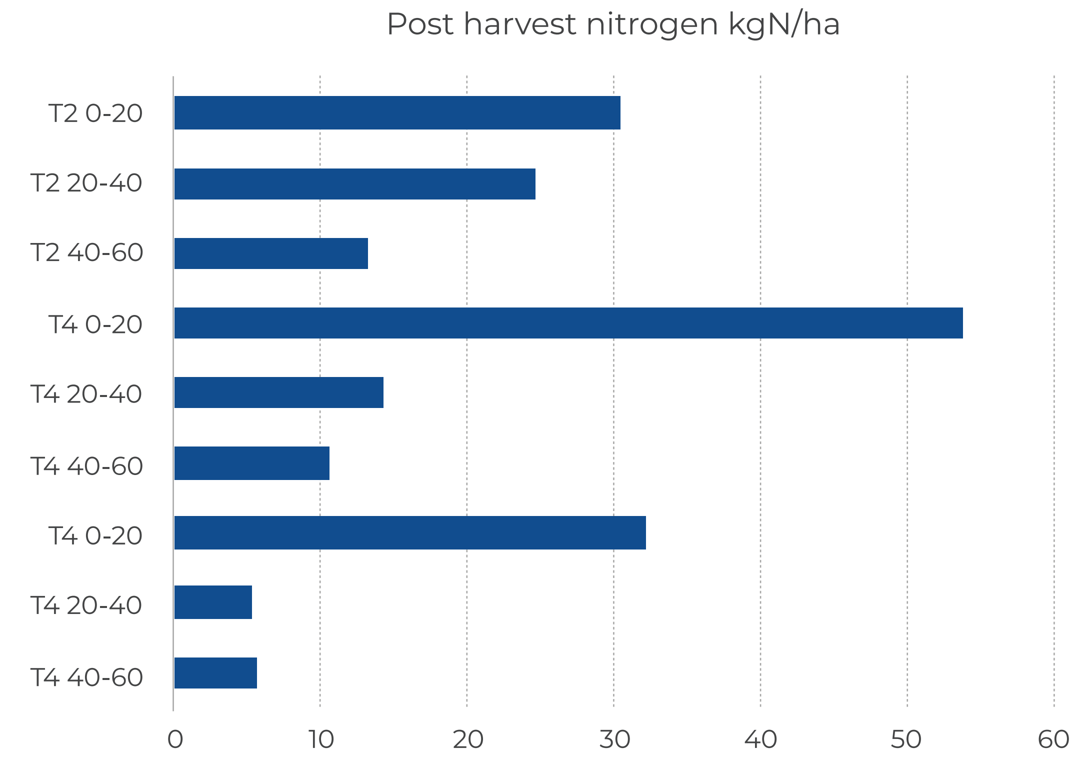

Figure 2 Post-harvest residual nitrogen levels (kg/ha) in T2 Cut low, T4 cut low deep incorporation, T8 Burn

2023 pH results compared to 2022

Sampling of soil pH in January 2023 showed that the high rates of lime (6.7t/ha) applied in 2022 increased all the pH levels of treatments tested by between 0.8 and 1.5 units in the 0-10cm layer (Figure 3). The pHCaCl of these treatments after liming was 5.8 or higher, which is the optimum level to treat subsurface acidity.

The weak calcium chloride solution pH test (pHCaCl) increased by a small amount in the 10-20cm layer with all treatments tested increasing by between 0.1 and 0.5 units. The 10-20cm soil test results are not consistent with current research and require further testing to determine the effect of treatments on soil pH in the 10-20cm layer.

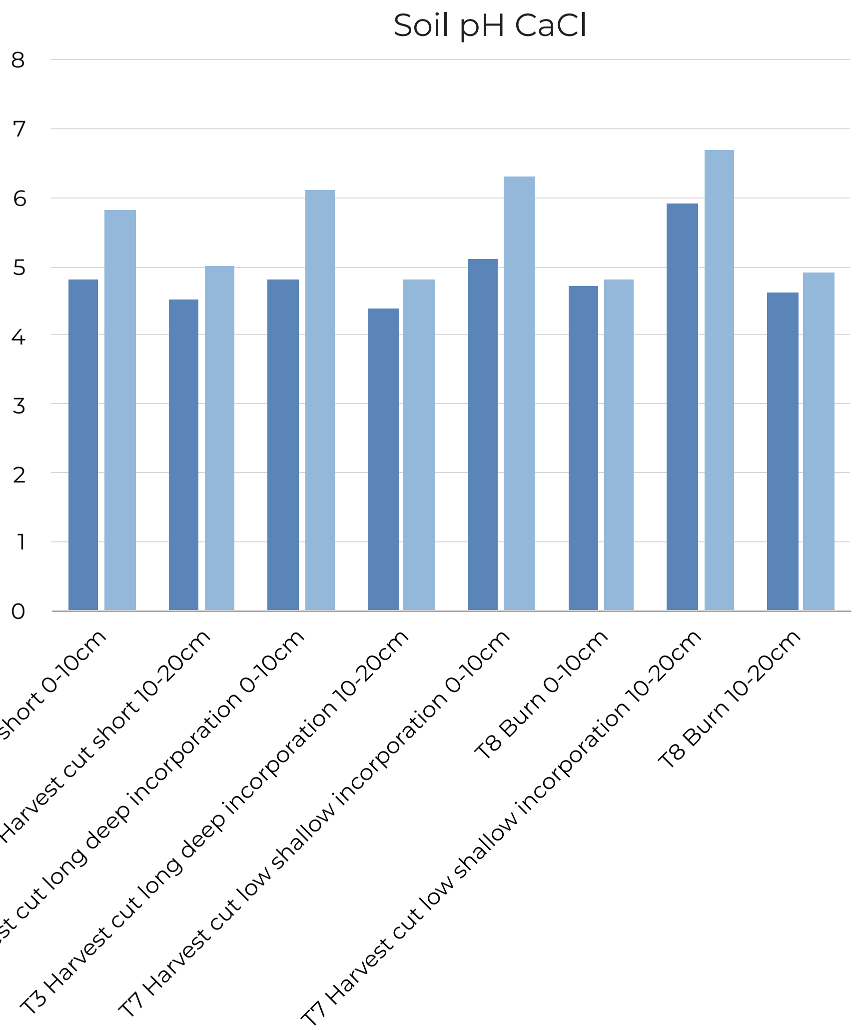

Figure 3 Soil pH levels before and after 6.7t/ha lime with different stubble treatments

OBSERVATIONS AND COMMENTS

The yields and quality across the treatments were extremely variable, due to the very high rainfall received, which caused water logging stress for the crop at the critical time of flowering and grain fill. The difference between treatments was more due to the level of waterlogging within the geography of the paddock, rather than a treatment effect.

Of the seven different options that were tested for stubble retention, three options were lower in cost compared to the burning treatment, which was estimated to cost $55/ha (based on labour costs for burning and nutrient losses by burning). These treatments were post-harvest treatments, including flail mulching, shallow incorporation using a speed tiller and baling straw and cost in the order of $37 - $45/ha. More expensive options were cutting low at harvest with and without deep or shallow incorporation of the stubble, which cost $160- $285/ha.

The deep incorporation of stubble and lime treatment (T3 and T4) was to investigate the practice of deep incorporation of stubbles to mix the lime and wheat residue evenly throughout the 0-15cm layer. This cannot be achieved through surface application or shallow incorporation with a speed tiller. Over the past two to three years, soil testing in the region has shown that surface applied lime is sitting in the top 2-5cm and not moving down the profile due to dry seasons.

A deep incorporation of lime would be used in a situation where a high rate of lime is required to address a subsurface acidity issue (below 10cm) and would be considered as a one in twenty-five-year treatment depending on crop removal of alkalinity. Given the high cost of this treatment, it is recommended that farmers seek advice to ensure the best possible outcome for the investment. In the demonstration, deep incorporation of lime was tested with either cutting the crop at normal height or cutting the crop low, to allow better incorporation. More testing is required on these two treatments to ascertain which treatment gave the best mixing of lime in the soil.

Even though the year turned out to be extremely wet, measurements taken after stubble treatments in the summer of 2021-2022 showed different soil moisture retention between treatments. The harvest cut short had the highest soil moisture retained, followed by the burning. The deep incorporation treatment had the lowest retained soil moisture. This demonstration showed that stubble retention had little effect on yield in 2022 when soil moisture was not limiting, however in drier years an extra 11mm in the soil at sowing (as seen in the stubble cut short treatment compared to the burn treatment), can make a difference of 220kg/ha of wheat, based on a water use efficiency of 20kg/ha/mm. With wheat valued at $350/t, this would represent an income of $77/ha.

Table 5. Grain nutrient removal by treatment, major nutrients

Appendix 1. Nutrient removal (major nutrients kg/ha and minor nutrients g/ha) from the treatments

GRAIN NUTRIENT REMOVAL KG/HA							
Treatment	Nitrogen	Phosphorus	Potassium	Sulphur	Calcium	Magnesium	Sodium
1	107	16.3	21.9	6.1	2	5.1	0.51
2	103	15.5	20.6	5.6	1.8	5.1	0.47
3	113	16.9	22.5	6.1	1.8	5.6	0.47
4	117	16.8	21.4	6.1	2	5.6	0.51
5	116	18	24.3	6.8	2.1	5.8	0.53
6	130	18.9	22.6	7	2.1	6.4	0.54
7	122	19.7	24.3	7.5	2.3	6.3	0.58
8	126	18.6	23.4	7.2	2.4	6	0.6

Table 6. Grain nutrient removal by treatment, minor nutrients

GRAIN NUTRIENT REMOVAL GRAMS/HA					
Treatment	Manganese	Iron	Copper	Zinc	Boron
1	347	383	13.2	96.9	5.1
2	334	348	11.3	94	8.5
3	306	306	16.9	103	4.7
4	316	260	17.3	102	10.7
5	382	355	21.2	111	5.3
6	389	335	19.4	113	7.6
7	406	354	16.8	116	14.5
8	360	348	17.4	114	12.6

Appendix 2. Cost of nutrient removal from baling straw

	NITROGEN	PHOSPHORUS	POTASSIUM	SULPHUR	TOTAL COST $/HA
*Nutrient removal straw kg/t	6.1	0.36	11.7	1.17	
Straw removed t/ha	1.7	1.7	1.7	1.7	
Kg removed /ha	10.4	0.6	19.9	2.0	
Nutrient cost $/kg	1.75	4.2	2	0.8	
Cost of nutrient removal $/ha	18.15	2.57	39.78	1.59	62.09

Appendix 3. Cost of nutrient removal from burning

	NITROGEN	PHOSPHORUS	POTASSIUM	SULPHUR	TOTAL COST $/HA
*Nutrient removal straw kg/t	6.1	0.36	11.7	1.17	
Straw removed t/ha	2	2	2	2	
Burning removal %^	88	0	0	75	
Kg removed /ha	10.7	0.0	0.0	1.8	
Nutrient cost $/kg	1.75	4.2	2	0.8	
Cost of Nutrient removal $/ha	18.79	0.00	0.00	1.40	20.19

*Source: Lee Menhenett, Incitec Pivot

^Source: Stubble retention in Southern Aust. BJ Scott

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Authors: Kate Coffey, Riverine Plains; Lee Menhenett, Incitec Pivot.