# Chapter 6.
# Closing the yield gap after sandy soil amelioration - Sherwood trial 2022

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### KEY MESSAGES

- Crop performance improved with the addition of extra nitrogen on an ameliorated soil at Sherwood in 2022.
- On the Delved Flat, district practice yield (3.1 t/ha) was enhanced by +1.2 t/ha with extra N, with a cost:benefit of 1:2.3.
- On the Clayed Hill, district practice yield (2.9 t/ha) was enhanced by +0.9 t/ha with extra N, producing a cost:benefit of 1:1.7.
- Additional P or K fertiliser alone did not impact wheat yields, but grain yields were always highest in the combo N+P+K, both shallow and deep; albeit these increases were little better than for N only.
- A nil fertiliser treatment had the lowest NDVI, maturity biomass and grain yield, confirming the importance of annual fertiliser application to produce economic yields.

## Background

Sandy soils often possess co-occurring constraints that limit grain yield, including water repellence, extremes in pH, high soil strength and poor nutrient fertility. Farmers in the Sherwood district have been progressively ameliorating these constraints over the past 30 years through combinations of delving, clay spreading and deep soil tillage.

Despite best efforts, in-crop observations show crop biomass and grain yields are still low after amelioration on the rises in this dune swale landscape. Target wheat grain yields range between 3.5 and 4.0 t/ha on the flats, which aligns with an economic water limited yield potential of 3.9 t/ha, based on rainfall data collected on-farm at sherwood from 2013 to 2022 (Table 1-2). However, on the hills, actual average yields are reported at 1.5 to 2.0 t/ha, which is well below the conservative water limiting yield potential (WLYP) for the landscape.

District practice fertiliser applications supply 100 kg nitrogen (N), 18 kg of phosphorus (P), and 11 kg of sulfur (S) per hectare, relying on 45 kg/ha of soil mineral N to meet crop needs (for a target yield of 3.5 t/ha). It is uncertain whether this fertiliser strategy is sufficient following deep soil tillage and mixing, as these practices dilute and redistribute nutrients and organic carbon through the soil profile.

The trials reported here evaluated the performance of agronomic practices designed to mitigate nutritional constraints in a sandy soil at Sherwood. Treatments were applied in two distinct zones: a flat which was delved and spaded; and a steep sand dune that was clay spread and spaded in 2019. The use of two zones enabled the yield limiting factors in each landscape to be identified, and maximum attainable yields to be quantified. This information is vital for informing future nutrient management strategies across ameliorated sandy dune swale landscapes.

***Table 1:*** Average monthly rainfall (mm) recorded at the MFMG Sherwood weather station (Jaeschke) for the years 2013-2022. GSR – Growing season rain, SFR – Summer fallow rain.

| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GSR | - | - | - | 21.0 | 34.2 | 37.0 | 67.6 | 69.9 | 48.9 | 34.5 | - | - | 313.1 |
| SFR | 16.6 | 10.5 | 12.3 | - | - | - | - | - | - | - | 16.3 | 13.9 | 69.6 |

***Table 2:*** Water limited grain yield potential and yield gap based on target/actual yields.

| | | |
|---|---|---|
| Summer Fallow Rain (SFR) mm | | 69.6 |
| Growing Season Rain (GSR) mm | | 313.1 |
| Crop water use (WU) = 0.25xSFR + GSR | | 330.5 |
| Water limited grain yield potential (PY) = 22 x (WU-110)/1000 t/ha | | 4.85 |
| **Economic yield target = 0.8*PY t/ha** | | **3.88** |
| **Delved Flat: actual average yield = 3.5 t/ha** | **Yield Gap** | **0.38 t/ha** |
| **Clayed Dune: actual average yield = 1.5 t/ha** | **Yield Gap** | **2.38 t/ha** |

## Activities

A paddock was selected at Sherwood (-35.986022, 140.605068) that was in its third season following amelioration. Water repellence and compaction were alleviated via amelioration, with clay content and cation exchange capacity also being raised to desirable levels for a sandy soil (Table 3). However, soil test results confirmed phosphorus (P), potassium (K), and copper (Cu) were below critical concentrations for a medium rainfall environment. Pre-sowing mineral nitrogen and organic carbon content were also low, despite following a bean crop in 2021 (Table 3).

***Table 3:*** Soil test results for 0-10 cm depth across two paddock zones.

| Zone | $pH_{Ca}$ | OC % | ECEC cmol+/kg | Clay % | Min. N | Col P (PBI) | Exch. K | S | Cu |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | mg/kg | | | | |
| **Delved Flat** | 7.53 | 0.60 | 7.81 | 3.3 | 7.3 | 8 (20) | 135 | 3.5 | 0.14 |
| **Clayed Dune** | 7.76 | 0.44 | 8.02 | 4.0 | 8.0 | 14 (16) | 88 | 2.8 | 0.16 |

It was hypothesised that the delved flat would be responsive to P, whereas the clayed dune would be most responsive to K. The depth of placement of these nutrients was also explored, given the surface application and incorporation of clay, and the subsurface horizons that are still devoid of nutrients after spading.

Additionally, a treatment was included that supplied adequate N to achieve the 4.9 t/ha water limited yield potential (as calculated in Table 2). Cu was also identified as being deficient, along with moderate S; both of these nutrients were supplied to all plots to eliminate them as constraining factors on yield.

Two identical trials were established, one on the delved flat and the other on the clayed dune, configured in a randomised block trial, with seven treatments and three replications. Scepter⁽ᴰ⁾ wheat was sown on 23 May 2022 at 225 plants/m$^2$, along with 8 kg/ha of copper sulphate and other fertilisers depending on treatment (Table 4).

P was supplied as MAP, banded with and below the seed in treatments 2 to 7. K was supplied as muriate of potash, banded below the seed in treatments 5 and 6. Fertiliser applied in treatment 7 was split three ways to include applications with the seed, below the seed and deep banded at 20 cm. Additional N was applied to treatments 3, 6 and 7 at sowing (+20 N kg/ha), GS12-13 (+14 N kg/ha), GS30 (+20 N kg/ha) and GS 40 (+46 N kg/ha) supplied as both urea and sulphate of ammonia. Pre-emergent, post emergent and in-crop applications of herbicide, fungicide and pesticide were used to eliminate weeds, disease, insects, rodents and slugs, as per district practice.

***Table 4:*** Seven treatments were applied to two identical trials at Sherwood in 2022.

| Treatment | | Nutrients supplied (kg/ha) from fertiliser | | | | |
|---|---|---|---|---|---|---|
| # | Name | N | P | K | S | Cu |
| T1 | Nil fertiliser | 0 | 0 | 0 | 0 | 2 |
| T2 | District practice | 100 | 18 | 0 | 11 | 2 |
| T3 | T2 + N | 200 | 18 | 0 | 11 | 2 |
| T4 | T2 + P | 100 | 27 | 0 | 11 | 2 |
| T5 | T2 + K | 100 | 18 | 20 | 11 | 2 |
| T6 | T2 + N + P + K shallow | 200 | 27 | 20 | 11 | 2 |
| T7 | T2 + N + P + K deep | 200 | 27 | 20 | 11 | 2 |

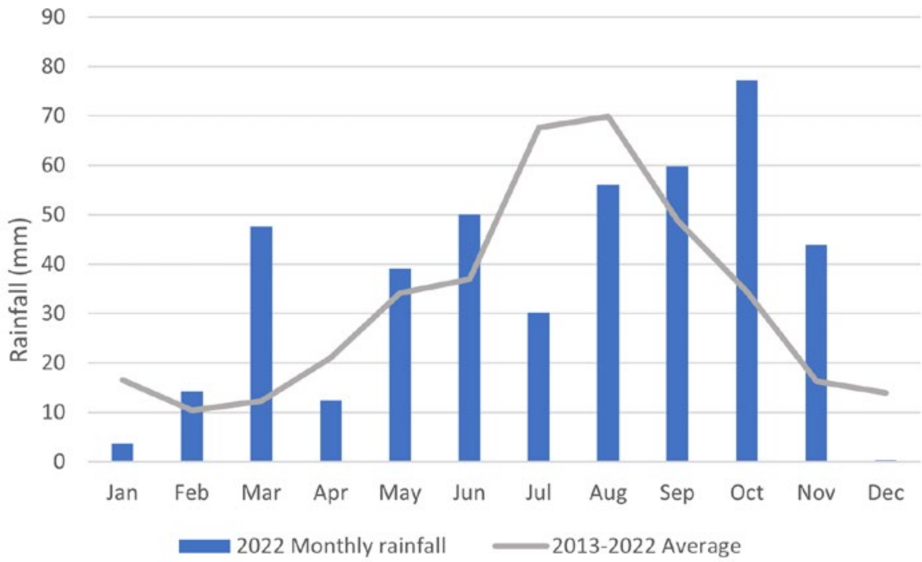


***Figure 1:*** Monthly rainfall (mm) recorded at the MFMG Sherwood Weather Station (Jaeschke) in 2022 (blue columns) and the average monthly rainfall recorded at that site since 2013 (grey line).

The growing season was characterised by a very dry start, followed by above average rainfall in June, below average rainfall in July and then a very wet spring (Figure 1). The growing season rainfall (GSR) totalled 325 mm, which was just above the long-term average GSR (Table 1).

Crop establishment was measured on 20 June and normalised difference vegetation index (NDVI) on 28 July, 11 August and 27 September. Maturity biomass was sampled on 6 December and grain yield and quality on 22 December. Results were analysed for significance ($P<0.05$) using ANOVA in GenStat.

## Results & Discussion

### Crop Establishment

The average plant populations were very similar on both flat and dune, averaging 140 and 139 plants/m2 respectively. Treatments did not affect crop establishment at either location.

### NDVI

Visual differences in above-ground biomass were observed between treatments from early tillering, both in terms of colour and quantity, which persisted until maturity. This was confirmed with NDVI at every collection date, with the nil fertiliser treatment always lower in comparison to district practice. NDVI was often improved with the combination of additional N+P+K fertiliser, compared to the district practice, particularly with deep placement of nutrition (Table 5 and photos 1 to 7).


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***Table 5:*** Normalised difference vegetation index measured in 2022 across the two locations.

| Treatment | Delved flat | | | | | | Clayed dune | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 28-Jul | | 11-Aug | | 27 Sept | | 28-Jul | | 11-Aug | | 27 Sept | |
| Bare earth | 0.20 | | 0.24 | | 0.23 | | 0.20 | | 0.24 | | 0.21 | |
| Nil fertiliser | 0.39 | a | 0.40 | a | 0.45 | a | 0.31 | a | 0.36 | a | 0.32 | a |
| District practice | 0.58 | b | 0.64 | bc | 0.80 | b | 0.46 | b | 0.56 | bc | 0.74 | b |
| + N | 0.64 | c | 0.69 | cd | 0.83 | b | 0.47 | b | 0.62 | bcd | 0.80 | bc |
| + P | 0.59 | bc | 0.64 | bc | 0.76 | b | 0.46 | b | 0.56 | bc | 0.74 | b |
| + K | 0.57 | b | 0.63 | b | 0.80 | b | 0.48 | b | 0.53 | b | 0.76 | bc |
| + N + P + K shallow | 0.64 | c | 0.68 | bcd | 0.82 | b | 0.50 | bc | 0.70 | d | 0.78 | bc |
| + N + P + K deep | 0.63 | c | 0.71 | d | 0.82 | b | 0.54 | c | 0.64 | cd | 0.81 | c |
| ***Mean*** | *0.58* | | *0.63* | | *0.75* | | *0.46* | | *0.57* | | *0.71* | |
| **P Value** | <.001 | | <.001 | | <.001 | | <.001 | | <.001 | | <.001 | |
| **LSD (0.05)** | 0.05 | | 0.06 | | 0.10 | | 0.06 | | 0.10 | | 0.07 | |
| **CV%** | 1.6 | | 2.8 | | 4.3 | | 13.6 | | 7.7 | | 1.7 | |

## Maturity Biomass

Wheat biomass (dry matter t/ha) was substantially impaired in the absence of any fertiliser in 2022, producing only 4.8 and 3.4 t/ha of dry matter on the Delved flat and Clayed dune, respectively. Under district practice, biomass was 7.1 t/ha on the Clayed dune compared to an extra 4.5 t/ha produced on the Delved flat (11.7 t/ha). This demonstrates the impact of soil type on plant growth in this environment. Biomass production was further improved with the addition of extra N fertiliser, adding more than 2.5 t/ha above the district practice in both locations (Table 6).

***Table 6:*** Harvest dry matter (DM) and wheat grain yield (t/ha) and protein (%) in 2022 for the two locations.

| Treatment | Delved flat | | | | | | Clayed dune | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dry matter | | Grain yield | | Protein | | Dry matter | | Grain yield | | Protein | |
| | t/ha | | t/ha | | % | | t/ha | | t/ha | | % | |
| Nil fertiliser | 4.80 | a | 1.62 | a | 10.0 | b | 3.36 | a | 1.17 | a | 9.7 | b |
| District practice | 11.7 | bc | 3.12 | b | 9.2 | a | 7.12 | b | 2.87 | b | 8.9 | a |
| + N | 14.3 | d | 4.36 | c | 10.6 | b | 9.66 | c | 3.78 | c | 10.2 | c |
| + P | 10.7 | b | 3.49 | b | 10.0 | b | 7.67 | b | 3.01 | b | 8.7 | a |
| + K | 11.5 | bc | 3.03 | b | 10.1 | b | 7.93 | b | 2.98 | b | 9.0 | a |
| + N + P + K shallow | 13.1 | cd | 4.62 | c | 10.4 | b | 10.71 | d | 3.94 | c | 10.8 | d |
| + N + P + K deep | 12.2 | bc | 4.37 | c | 10.3 | b | 9.99 | cd | 3.86 | c | 10.5 | cd |
| ***Mean*** | *11.2* | | *3.51* | | *10.1* | | *8.06* | | *3.09* | | *9.7* | |
| **P Value** | <.001 | | <.001 | | 0.027 | | <.001 | | <.001 | | <.001 | |
| **LSD (0.05)** | 2.07 | | 0.55 | | 0.72 | | 1.03 | | 0.318 | | 0.46 | |
| **CV%** | 10.2 | | 14.6 | | 3.4 | | 1.1 | | 9.8 | | 2.9 | |

## Grain Yield and Quality

Wheat grain yield was substantially impaired in the absence of any fertiliser in 2022, producing only 1.6 and 1.2 t/ha of grain on the Delved flat and Clayed dune, respectively. This result confirms the importance of annual fertiliser application to produce economic yields.

District practice fertility treatments increased grain yield to 2.9 t/ha on the Clayed dune, with an extra 0.25 t/ha produced on the Delved flat (3.1 t/ha), achieving 80 % and 74 % of the economic WLYP.

Grain yields were further improved with the addition of extra N fertiliser, adding 1.2 t/ha on the Delved flat and 0.9 t/ha on the Clayed dune (Table 6), compared to the district practice, and also boosted grain protein to above 10.0 %. The +N treatment on the Delved flat met APW receival standards; all other treatments achieved ASW1. This treatment closed the yield gap by 32 % on the flat, achieving 112 % of the economic WLYP, and by 23 % on the dune, achieving 97 % of the WLYP.

Despite suboptimal P on the flat and K on the dune, crop yields were not improved with the extra application of these nutrients in isolation, as hypothesised. It appears that the district practice annual P application (18 kg/ha) is sufficient to meet crop needs and exceeds what was removed in grain (approx. 11 kg P/ha). Therefore, background P fertility should improve with time. There was a visual response to K fertiliser observed at anthesis, but this did not translate through to additional grain yield. Small increases in yield were observed in the combination +N+P+K treatments, albeit these increases (+0.15 to +0.3 t/ha) were not significant in comparison to +N only.

***Photo 1:*** Nil

***Photo 2:*** District practice

***Photo 3:*** +P

***Photo 4:*** +K

***Photo 5:*** +N

***Photo 6:*** +N+P+K Shallow

***Photo 7:*** +N+P+K Deep

***Photos 1-7 :*** Differences in crop vigour were evident throughout the season, as seen here on 17 August 2022 *(Mel Fraser – Soil Function Consulting).*

### Economics

Using a conservative average urea price of $800/t, and a ASW grain price of $300/t, the additional fertiliser cost equates to $160/hectare (200 kg urea) with an additional income of $372/ha on the Delved flat and $273/ha on the Clayed dune. Each additional dollar invested in urea in 2022 returned an additional $2.30 on the flat and $1.70 on the dune (Table 7).

***Table 7:*** Economics of supplying 100 kg/ha of additional N fertiliser, using a conservative urea price of $800/t and $300/t for ASW.

| | Yield increase above control (t/ha) | Additional income/ha | Additional urea expense/ha | Cost:benefit |
|---|---|---|---|---|
| Delved flat | +1.24 | $372 | $160 | 1:2.3 |
| Clayed dune | +0.91 | $273 | $160 | 1:1.7 |

## Conclusions

NDVI, biomass, grain yield and protein were all enhanced with the addition of extra nitrogen (N) fertiliser (+100 kg/ha above district practice) on two ameliorated soils at Sherwood in 2022. On the Delved flat, district practice yield was enhanced by +1.2 t/ha with extra N, producing a cost:benefit of 1:2.3. On the Clayed dune, yield was enhanced by +0.9 t/ha with a cost:benefit of 1:1.7.

Additional P and K fertiliser did not impact wheat yields when applied on their own, but grain yields were always the highest in the combo N+P+K, both shallow and deep. A nil fertiliser treatment had the lowest NDVI, maturity biomass and grain yield.

Results show that the yield gap can be substantially closed on ameliorated soils when nutritional strategies are matched to water limited yield potential. The optimum economic rate of N fertiliser has not been determined and warrants further exploration on ameliorated soils.

## Acknowledgements

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This GRDC funded project aims to strengthen grower confidence in successfully establishing crops post-soil amelioration and optimising their agronomic management. Via a two-year series of demonstration trials, soil characterisations and associated extension activities, the targeted project outcome is for 25% of grain growers and their advisors engaging with ameliorated sands in the Upper South East to:

- have adopted management techniques that maximise profitability from ameliorated soils and manage risks of poor crop establishment and wind erosion.
- the ability to re-characterise their soils post-amelioration, including water holding capacity, plant available water, texture, changes in nutrient or constraint distribution, and constraint identification.
- be managing ameliorated soils to their newly established economic yield potential.

This project is funded by the Grains Research and Development Corporation (GRDC).


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