

Final Technical Results Report 2025

Increasing the effectiveness of clayey within the Albany Port Zone

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REPORT SENSITIVITY

Does the report have any of the following sensitivities?

Intended for journal publication	YES ☐ NO ☒
Results are incomplete	YES ☐ NO ☒
Commercial/IP concerns	YES ☐ NO ☒
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ABSTRACT

This project investigated the efficiency and best practices of claying as an amelioration strategy for non-wetting soils in the South Coast region of Western Australia, focusing on sandy and gravelly soil types common in the Albany Port Zone. Conducted between 2022 and 2024, four demonstration trials were established at Kojaneerup South, Scotts Brook (two sites), and Woogenellup. The trials aimed to improve grower knowledge of clay quality, optimise clay application rates, and assess the most effective clay incorporation methods and depths, while exploring the novel application of claying on gravel soils.

Results confirmed that achieving a target topsoil clay content of approximately 5% effectively alleviated non-wetting issues in sandy soils, improving plant establishment and grain yields, particularly in the first year following treatment. The project found that excessive clay application on sandy soils beyond the 5% threshold offered limited yield/economic benefit.

Trials on gravelly soils demonstrated that despite high gravel content, sufficient clay application remains critical to improve soil wetting (particularly in forest gravels with high OM content), with strategic tillage also contributing to yield improvements. Additionally, the effectiveness of different incorporation methods on gravel soils varied, with deeper inversion tillage (e.g., plozza plough) providing better initial crop establishment on these soils compared to shallower or less thorough mixing methods.

Water repellence, measured by MED tests, showed significant improvement across all sites post-claying. Soil strength, NDVI and grain quality impacts were variable.

Overall, the project highlighted the cost-saving potential of optimised clay rates and incorporation practices, and provided growers with practical knowledge on clay source assessment, application rates, and equipment use. Continued monitoring of the trials, especially in forest gravel soils (i.e., Scotts Brook trials), is recommended to evaluate long-term impacts of claying.

EXECUTIVE SUMMARY

Non-wetting soils are a significant constraint to agricultural productivity in the South Coast and Great Southern regions of WA. These soils reduce water infiltration and availability to crops, causing patchy germination, poor plant establishment, and ultimately lower yields. Claying has long been recognised as an effective amelioration strategy to improve soil wetting and crop performance. However, until recently, machinery limitations resulting in higher than necessary application rates have made claying an expensive and sometimes inefficient practice.

This project, conducted between 2022 and 2024, set out to refine and optimise claying practices to improve efficiency, reduce costs, and better suit the variable soil types of the region, including sandy soils with low organic matter and gravelly soils where claying is a relatively novel approach. Four trial sites were established at Kojaneerup South, Scotts Brook (two sites), and Woogenellup to evaluate clay source quality, application rates, incorporation methods, and the subsequent impacts on soil properties, crop establishment, plant health, and grain yield and quality.

Trial Methodologies:

Kojaneerup South (2022–2024):

Treatments tested varying clay application rates aimed to reach different target (post amelioration) soil clay percentages by incorporation to 15cm. The rates were 140 t/ha (below 5% clay content threshold), 270 t/ha (approximately 5.8% clay content) and 350 t/ha (above 5% clay content).

Scotts Brook (1) (2022–2024):

A standard clay rate (400 t/ha) was applied to a forest gravel soil, testing different incorporation methods and depths. The incorporation methods were plovza plough (30cm incorporation), Offset chisel plough (15cm incorporation) and Speed tiller (10cm incorporation), all compared to an untreated control (no clay or tillage).

Woogenellup (2023–2024):

Clay was applied at two rates (100 t/ha and 200 t/ha) to a gravelly sand soil and incorporated to 10cm. These treatments were compared to a tilled only treatment and an untreated control (no clay or tillage).

Scotts Brook (2) (2023–2024):

Clay was applied at three rates (70 t/ha, 100 t/ha and 200 t/ha) to a forest gravel soil (65-70% gravel) with high organic matter, and incorporated to 15cm. These treatments were compared to a tilled only treatment and an untreated control (no clay or tillage).

Key Findings:

- Clay Content Threshold: Achieving a topsoil clay content of approximately 5% (0-15cm depth) was confirmed as the critical target for effectively alleviating non-wetting in sandy

soils. Below this threshold, soils retained some water repellence, reducing plant establishment and yields.

- **Clay Rates and Economic Efficiency:** At the Kojaneerup South site, increasing clay rates to increase soil clay content beyond the 5% threshold was not economical. The medium rate (270 t/ha) achieved the target clay content and delivered the most cost-effective yield improvements compared to higher rates (350 t/ha). This represents a significant potential saving by reducing unnecessary additional clay applications.
- **Incorporation Techniques in Gravel Soils:** The Scotts Brook (1) site, characterised by forest gravels, demonstrated the challenges of clay incorporation into gravelly soils. The plozza plough, which inverts soil to 30cm, mixed clay most effectively and produced the highest initial plant establishment and yields. Shallower incorporation methods struggled to adequately mix clay with gravel, resulting in surface “clay capping” and reduced crop performance.
- **Claying on Gravelly Sands:** The trial at Woogenellup, on a gravelly sandy duplex, showed that even in soils with 20-35% gravel, achieving 5% clay content in the soil matrix remains important. The 200 t/ha clay rate incorporated to 10cm achieved this threshold and produced the highest yields in 2023 and 2024. Tillage alone had some positive effect on yield but was less effective than claying and tillage.
- **Forest Gravel Soils:** At the second Scotts Brook site, high gravel (65-75%) and organic matter (>3.5%) complicated the determination of optimal clay rates. Although clay treatments increased clay content well above 5% and improved soil wetting, there was no significant impact on plant establishment or yield in the two years observed. Seasonal conditions—dry sowing followed by heavy June rainfall—likely masked treatment effects on non-wetting. Continued long-term monitoring of the Scotts Brook sites is recommended to assess permanent benefits of claying in such soils.

Learnings for Growers:

Achieving the 5% clay content threshold remains a reliable rule of thumb for sandy soils to overcome non-wetting, and achievement of a higher clay content does not significantly increase yields (to cover cost of higher rate application). In gravelly sandy soils, clay application to achieve 5% final clay content (gravel removed) remains critical. In forest gravels, careful consideration of incorporation depth and equipment is important to ensure effective soil mixing. It is currently unclear if claying is a benefit to production on forest gravels over and above the benefits (albeit not a permanent fix) of strategic tillage. Ongoing monitoring, of claying on these soil types with high organic matter, is necessary to fully understand long-term benefits and refine best practice guidelines.

BACKGROUND

Clay spreading adds clay enriched (>20%) soil into clay deficient and water repellent topsoils. In very sandy soils, clay is incorporated to depths of 50cm, depending on the equipment available. The overall aim is to lift the clay content of sandy soils up to 5%. Claying topsoils reduces water repellence, water and wind erosion risk, increases water holding capacity, and has the potential to increase organic matter and carbon over time.

Claying has become a vital amelioration tool in the Great Southern region and along the South Coast of WA. The soils in this region are typically sandy, low in organic matter, non-wetting and prone to wind erosion. Claying significantly increases grain yields on these sandy duplex soils by ameliorating one or more of these constraints (predominately non-wetting).

It has been implemented widely across the deep sandy duplex soil zones in southern WA and SA. However, the adoption of new machinery has allowed farmers to be more precise when applying clay. Prior to the adoption of large spreaders that could better tailor clay rates, farmers were utilising road working equipment, which applied large tonnages of clay that then needed to be spread or smoothed across the paddock. This resulted in farmers being unable to apply low rates of clay >300t/ha, which then resulted in a lot of time and money spent on smudging and incorporating the clay after it was applied.

Even with improved machinery/technology claying is expensive and grower strategies for determining clay spreading rates have been relatively ad-hoc and rarely quantified accurately. This project was driven by local growers and advisers who were keen to improve the efficiency of claying operations. When the project commenced, it was with the aim to improve growers' knowledge of on-farm clay quality and refine their decision making on how much clay should be applied and what incorporation method should be used (including incorporation depth considerations).

As the project progressed through its first year, and based on the successful adoption of claying sandy soils to alleviate non-wetting, growers with sandy gravels and forest gravels facing similar non-wetting issues, were keen to assess the benefits of claying gravel soils. After encouraging preliminary results in 2022, a variation to the project was approved by GRDC to invest in further research in 2023. The aim was to further quantify the benefits to production and to further explore what clay rates are necessary to alleviate non-wetting issues in gravel soils, with consideration of gravel content.

Under the variation (in collaboration with Southern Dirt), Stirlings to Coast Farmers (SCF) established two additional demonstration trials in 2023, one in Woogenellup on a gravelly sand over clay, and the other in Scotts Brook on a loamy forest gravel. The trial site at Woogenellup had two distinct zones across the demonstration site, a dense gravel (60% gravel content) on the hilltop and a sandy gravel (40% gravel content) on the slopes. It provided a great opportunity to test the impact of claying (at two clay rates) across both zones. It should be noted that the organic matter at this site was low. The Scotts Brook site was located on a dense forest gravel with 65-70% gravel by weight. The loamy soil had a clay content of 4.8%, but also a high organic matter content of 3.68% (the main contributor to the non-wetting).

PROJECT OBJECTIVES

This project aimed to increase the efficiency of claying by improving growers' knowledge of on-farm clay quality, refining their decision making on how much clay should be applied, and determining the best clay incorporation method (including incorporation depth).

Given the new machinery/technology, this project also aimed to assess where efficiencies could be achieved, and what technology and rates would be optimal for farmers to adopt.

As a later addition, the project also aimed to assess the value of applying clay to sandy gravels and forest gravels. Based on the successful adoption of claying sands to alleviate non-wetting, growers with gravel soils were keen to assess the benefits of claying gravel soils, which also have significant non-wetting issues.

As part of the project four demonstrations trials were established, two in 2022, and two in 2023, and a series of two workshops were run (in collaboration with David Hall, DPIRD) with the aim of providing growers with the key information they needed to implement best practice.

GRDC Investment Outcome:

By 2024, Growers spreading, or intending to spread clay, will have increased ability to assess on-farm clay sources, and have methods to better monitor clay application rates.

METHODOLOGY

Four individual trials were established throughout the project, two in 2022, and two in 2024. Each trial, although similar in design, had a different objective and differing treatments, with the aim to demonstrate and inform farmers of best claying practice.

Trial Designs - 2022

In 2022, two demonstration sites, located in Kojaneerup South and Scotts Brook had clay spread in the autumn of 2022, after which they were seeded with a cereal crop. The clay was applied with contractors' equipment (CAT Scraper) at Scott's Brook and the farmer's equipment ('SPREAD-IT' spreader) at Kojaneerup South.

Kojaneerup South

Site description:

The 2022 trial site at Kojaneerup South was established on a deep sandy duplex, with sand over a compacted gravelly clay duplex layer at approx. 60cm. The topsoil (10cm) which makes up the primary non-wetting zone, had a high sand percentage (92.8%), low clay percentage (1.13%) and a low OC content (1.72). The site had been in continuous cropping for the past decade, and the host farmer had undertaken claying on other parts of his property prior to the trial commencing.

Trial Design:

At the Kojaneerup site, three treatments were applied, a low (140 t/ha), a medium (270 t/ha) and a high clay rate (350 t/ha), as well as a small nil clay control strip. The farmer applied 300t/ha across the rest of the paddock. All three of the treatment zones were incorporated with off-set discs to a depth of 150mm.



Figure 1: Kojaneerup South Trial Design

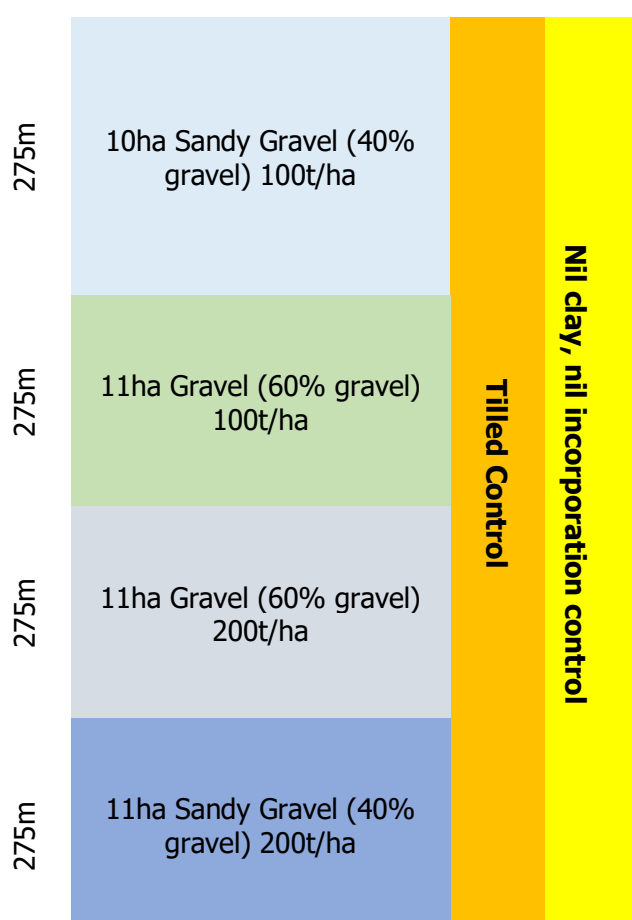


Figure 3: Trial design, Woogenellup, 2023.

Scotts Brook 2

Site description:

The second Scotts Brook trial site was established on a forest gravel soil with a high gravel percentage of 50-60%, a relatively high clay percentage for a non-wetting soil 4.8%, a sand percentage of 88%, and a high organic carbon content of 7.8%. The area had been in a 7-year cropping rotation, prior to that it was in long term pasture.

Trial Design:

The Scotts Brook (2) trial design (Figure 4) included three clay rate treatments (70t/ha, 100t/ha and 200t/ha). The clay across all treatments was incorporated with a speed tiller, to a depth of approximately 15cm. Again, the two control treatments included a tilled only treatment and a nil clay, nil incorporation treatment.

12m	12m	12m	12m	12m	12m	12m	12m	12m	12m	12m
Cont. 1 *	Cont. 2 #	100 t/ha clay & Incorp	200 t/ha clay & Incorp	70 t/ha clay & Incorp	Cont. 2	Cont. 1	200 t/ha clay & Incorp	100 t/ha clay & Incorp	70 t/ha clay & Incorp	Cont. 2

* Cont 1 - Nil clay, nil incorporation, # Cont 2 - Speedtill only, nil clay.

Figure 4: Trial design, Scotts Brook, 2023

Monitoring and Measurement

The following measurements were undertaken in 2022 and 2023 across both newly established sites.

- Baseline soil sampling 0-10cm and 10-30cm (incl. gravel, clay and OM content)
- Baseline water repellence assessments (MED test)
- Clay source - clay fraction determination
- Plant establishment counts
- Follow-up MED testing after clay application
- Biomass Assessment
- Soil strength at field capacity (somewhat difficult in gravel)
- Grain yield (farmer machinery) and quality

The 2022 and 2023 established were continuously monitored through to the end of the 2024 growing season, with the following measurements taken.

- NDVI
- Plant establishment
- Grain yield and quality

LOCATION

Where field trials have been conducted, provide the following location details in the table below: latitude and longitude, or nearest town. (Add additional rows as required.)

Site #	Latitude (decimal degrees)	Longitude (decimal degrees)	Nearest town
Trial Site #1	-34.5186228	118.3336234	Kojaneerup South
Trial Site #2	-33.882945	116.7268457	Scotts Brook 1
Trial Site #3	-34.4910546	117.9576775	Woogenellup
Trial Site #4	-33.888944	116.7958721	Scotts Brook 2

If the research results are applicable to a specific GRDC region/s (e.g. North/South/West) or [GRDC agro-ecological zone/s](#), indicate which in the table below:

Research	Benefiting GRDC region (select up to three)	Benefitting GRDC agro-ecological zone	
Increasing the effectiveness of clayey within the Albany Port Zone	Western Region Choose an item. Choose an item.	☐ Qld Central ☐ NSW NE/Qld SE ☐ NSW Vic Slopes ☐ Tas Grain ☐ SA Midnorth-Lower Yorke Eyre ☐ WA Northern ☐ WA Eastern ☐ WA Mallee	☐ NSW Central ☐ NSW NW/Qld SW ☐ Vic High Rainfall ☐ SA Vic Mallee ☐ SA Vic Bordertown-Wimmera ☐ WA Central ☒ WA Sandplain

RESULTS

Clay Test Results & Final Soil Clay Content

2022 Established Sites

Clay samples from the clay pits at both Scotts Brook and Kojaneerup South were taken prior to spreading the clay in 2022. The clay pit at Kojaneerup South was a purposely dug clay pit, at a location on the farm, where the farmer knew there was an enriched clay deposit. The clay pit at Scotts Brook was dug as part of pre-existing plans to expand a dam within the paddock the trial was taking place in.

Kojaneerup South

The clay samples at the Kojaneerup site were taken from a pit that ranged from a depth of 100cm below the soil surface to a depth of 300cm below the soils surface. The clay was then deposited and mixed in a pile, to ensure a relatively uniform clay product was spread across the paddock.

The clay used in the Kojaneerup trial had an average clay fraction of 40.4%. Table 1 shows the resulting topsoil clay percentage after the clay had been applied at the three different rates. The resulting clay content is a factor of three elements, the initial clay percentage in the topsoil, the clay fraction of the clay to be spread and the incorporation depth to 15cm.

Table 1: Clay content increases with each rate of clay applied (Kojaneerup South)

Clay application rate	350t/ha	270t/ha	140t/ha
Ameliorated topsoil clay %, incorporated to 150mm	7%	5.8%	3.8%
Total Increase in clay %	5.3%	4.1%	2.1%

Scotts Brook

The clay deposits at the Scotts Brook site were taken from a pit that ranged from a depth of 1.5m to 2m below the soil surface. The clay deposits for testing were taken at differing depths of the clay pit and not mixed to replicate the potential change in the clay fraction as the scraper deepened the pit. At Scott's Brook, the initial clay percentage in the topsoil was 4.4%, the clay fraction of the applied clay was 24.6% and the incorporation depth varied between 10 and 30cm depending which implement was used.

The initial clay percentage of 4.4% was quite high for a paddock that is to be clayed (Table 2), however, the soil had a high organic carbon (OC) percentage, ranging between 3.3 and 5%. It should also be noted that although the chisel had a deeper incorporation depth than the speed tiller, it did a poor job of mixing the soil and breaking down the aggregates of clay. This resulted in surface clay still being visible within the chisel plough plots, remaining in clumps, which undoubtedly had a negative impact on the crop production. Table 2 shows the increases in soil clay content after each of the treatments were implemented.

Table 2: Clay content increases for each treatment (Scotts Brook)

Implement	Incorporation depth	Initial clay %	Resulting clay %	change in clay %
Speed Till	10cm	4.4	10.7	6.3
Offset Chisel Plough	15cm	4.4	8.6	4.2
Plozza Plough	30cm	4.4	6.5	2.1

2023 Established Sites

Woogenellup

The clay at the Woogenellup site was taken from a new pit, where approximately 1 metre of sand and gravel topsoil was first removed. The clay had a high clay content at 36.74% (Table 3).

Table 3: Average clay source test results, Woogenellup, 2023.

Site	Clay %	Gravel %	P	K	S	PBI	pH
Woogenellup	36.74	5	4	381	38.4	25.9	7

Scotts Brook

The clay at the Scotts Brook site was excavated out of a dam that was being extended, and the clay source was dug from a depth of between 50cm to 2m. The average clay fraction of the clay was 28.07% (Table 4).

Table 4: Average clay source test results, Scotts Brook, 2023.

Site	Clay %	Gravel %	P	K	S	PBI	pH
Scotts Brook Clay	28.07	15%	8.5	67.3	99	142.7	6.7

Final Topsoil Clay Percentage - 2023 sites

The amelioration effect of each treatment at both the Woogenellup and the second Scotts Brook sites was driven by the combination of the clay fraction of the applied clay, the depth of incorporation, the initial clay content of the soil, and the percentage of gravel in the soil. Although the rates of clay applied across both sites are very low for conventional claying, the high gravel content in the soil meant that within the soil zone there was less non-wetting sand that needed to be ameliorated in comparison to a non-gravelly sand. Table 5 shows the initial clay content of the soil, and the resulting clay content after the clay had been applied and incorporated (final clay %) for both the Woogenellup and Scotts Brook (2) sites.

Table 5: Impact of clay treatments on final soil clay content at each site (Woogenellup & Scotts Brook), across each treatment, 2023.

Site	Starting Clay %	Clay Percentage	Rate	Incorporation Depth	Gravel %	Final Clay % (Soil Fraction)	Approx. Clay% of the soil (gravel removed)
Woogenellup	1.45	36.74	100	10cm	20	3.1	3.875
Woogenellup	1.45	36.74	200	10cm	20	4.7	5.875
Woogenellup	1.45	36.74	100	10cm	35	3.1	4.278
Woogenellup	1.45	36.74	200	10cm	35	4.7	6.486
Scotts Brook	4.8	28.7	70	15cm	40	5.6	7.84
Scotts Brook	4.8	28.7	100	15cm	40	5.9	8.26
Scotts Brook	4.8	28.7	200	15cm	40	7	9.8

Water Repellence

MED testing was conducted on soil samples from all trial sites prior to and post applications of clay. MED testing is a measurement of water repellence, with a scale from 0-5 based on the concentration of Ethanol required for a soil to wet up in five seconds. Tables 6-9 show the impact of claying on the MED results (non-wetting) for each site. There was an improvement in the MED test results across all trials, post clay application.

Table 6: MED test results prior to and post clay application – Kojaneerup South

MED Test	Kojaneerup 140t/ha	Kojaneerup 270t/ha	Kojaneerup 350t/ha
Baseline	4	4	4
Post – Amelioration	2	0	0

Table 7: MED test results prior to and post clay application – Scotts Brook (1)

MED Test	Scotts Brook (1) 400t/ha
Baseline	4
Post – Amelioration	0

Table 8: MED test results prior to and post clay application – Woogenellup

MED Test	Woogenellup 100t/ha	Woogenellup 200t/ha
Baseline	2	2
Post	0	1

Table 9: MED test results prior to and post clay application – Scotts Brook (2)

MED Test	Scotts Brook 100t/ha	Scotts Brook Control
Baseline	3	3
Post – Amelioration	0	2

Soil Strength

Soil Strength was only measured at the 2023 implemented sites, Woogenellup and Scotts Brook (2). Penetrometer readings were taken at the Woogenellup site on the 10 July 2023. As a result of the soil type, a very shallow sandy duplex where approximately 20-30cm of gravelly sand sits atop a highly compacted coffee rock/ironstone layer, the root restriction zone (3000kPa), was largely dictated by the gravel and depth to duplex layer rather than any specific impact as a result of claying. It should be noted that the light tillage resulting from the incorporation of the clay resulted in a slight reduction in compaction compared to the control (Figure 5). The highly compacted gravel duplex meant that some of the treatments could not be assessed to the full 700mm.

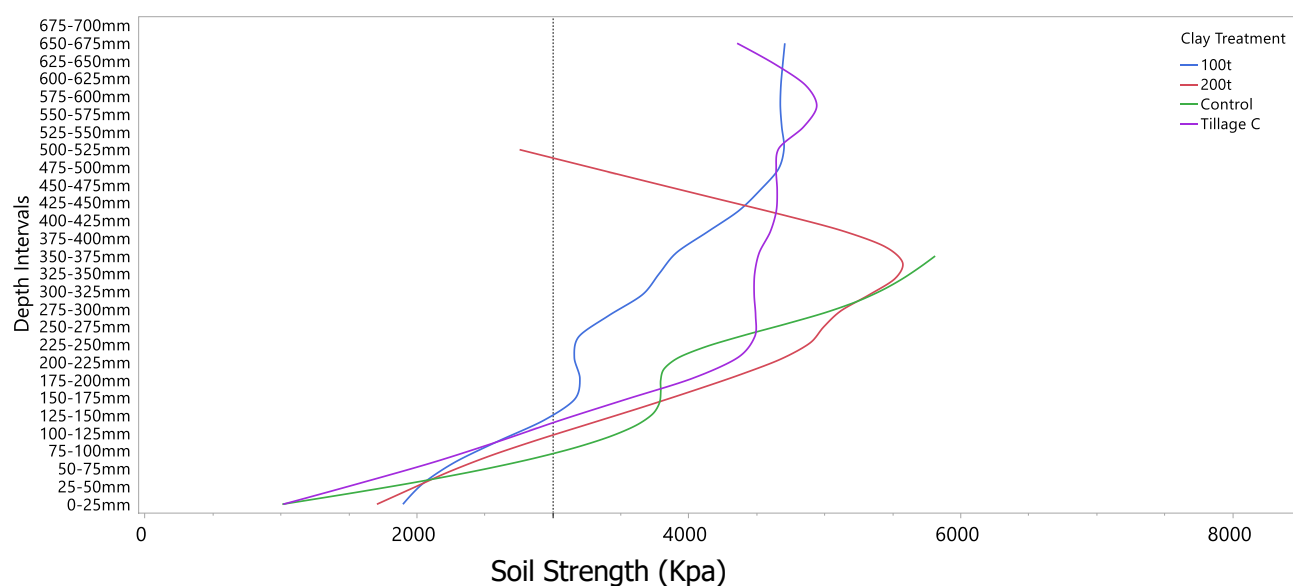


Figure 5: Mean soil strength per depth interval at Woogenellup, 2023. Note: due to the highly compacted duplex layer, some treatments were unable to be measured maximum depth (700mm) depth.

The Penetrometer data at the Scotts Brook (2) site showed no significant effect of claying rate on the soil strength (Figure 6). There was an extremely high soil strength across all treatments due to the high gravel content rather than a mechanical induced compaction.

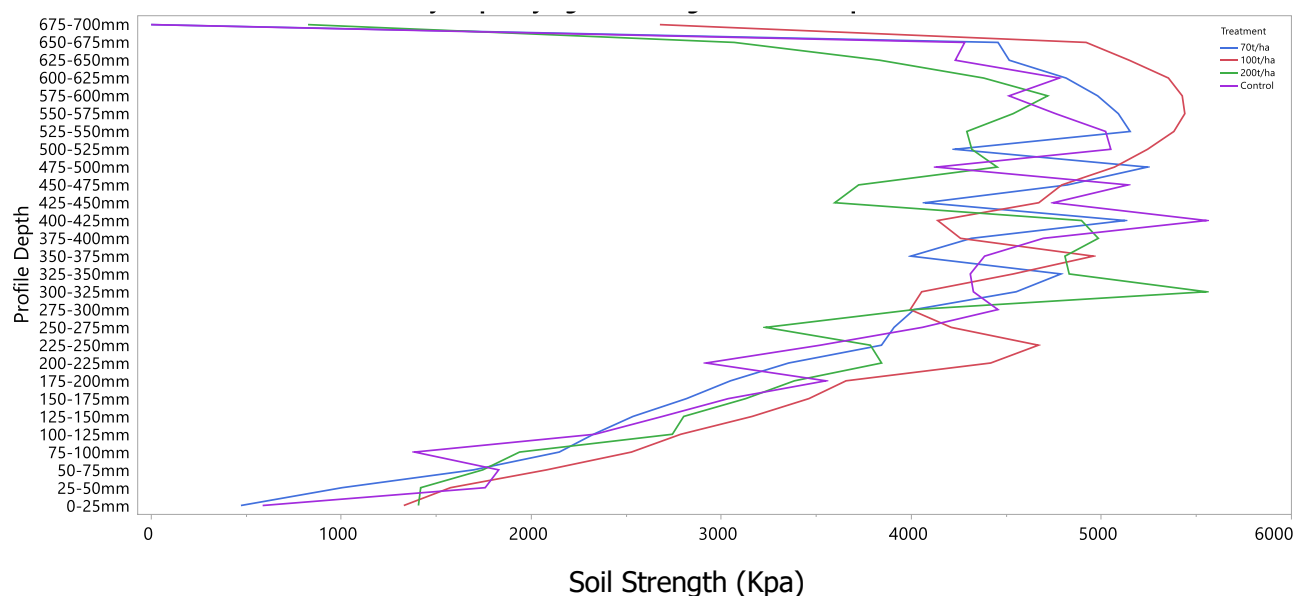


Figure 6: Mean soil strength per depth interval at Scotts Brook (2), 2023.

Plant Establishment Counts

Kojaneerup South

Plant establishment in 2022, 2023 and 2024 at the Kojaneerup South trial site, located on a deep sandy duplex, showed adequate plant numbers across all clay treatments, however, plant numbers were higher as the clay rate increased (Figure 7). This indicates that non-wetting alleviated by the claying had a positive impact on the plant establishment at this site.

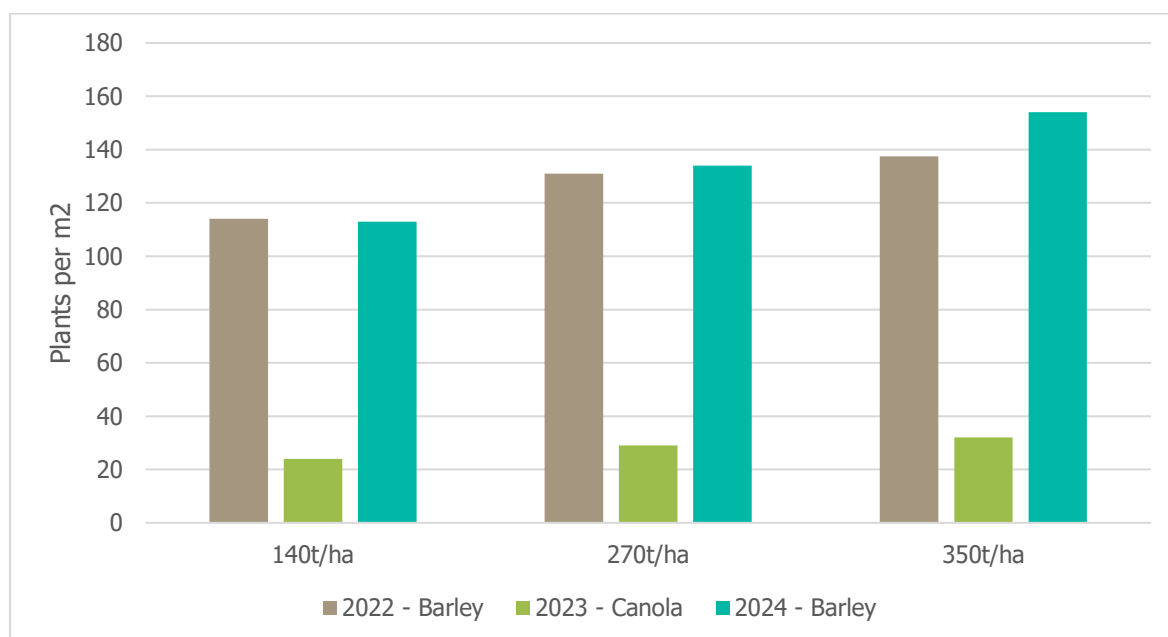


Figure 7: Average plant establishment counts across each treatment at the Kojaneerup South site in 2022, 2023, & 2024.

Scotts Brook (1)

Plant establishment across 2022, 2023 and 2024 at the first Scotts Brook trial site was variable (Figure 8). Barley plant numbers in the first year of the trial were below recommended numbers in all treatments except the plozza plough treatment. The same followed for the canola in 2023. By 2024, it was evident that the positive tillage effects of the plozza plough (and to a lesser degree the speed till and chisel plough) were wearing off and plant numbers were highest in the untreated control treatment. This data shows that there was less of an impact of the clay (same rate spread across all treatments except UTC), compared to the tillage effect of the plozza plough on non-wetting.

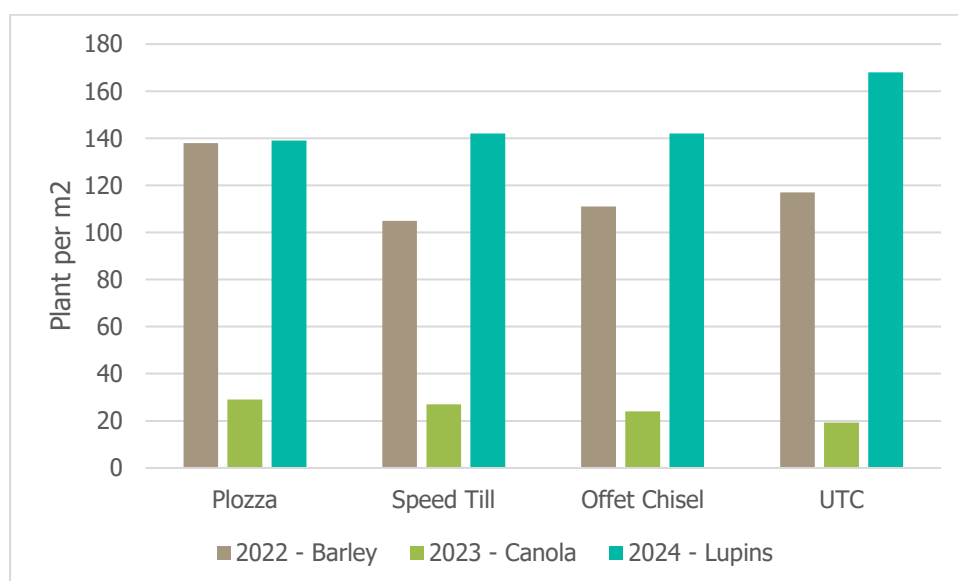


Figure 8: Average plant establishment counts across each treatment at the Scotts Brook Site (1) in 2022, 2023, & 2024.

Woogenellup

Plant establishment counts conducted in 2023 and 2024 at the Woogenellup trial site show that claying had a more positive impact on plant establishment in year one compared to in year two (Figure 9). Interestingly in year two, plant numbers were higher in the 100 t/ha clay treatment compared to the 200 t/ha treatment and controls. It suggests that the lower rate in gravelly soil, was enough to alleviate non-wetting issues.

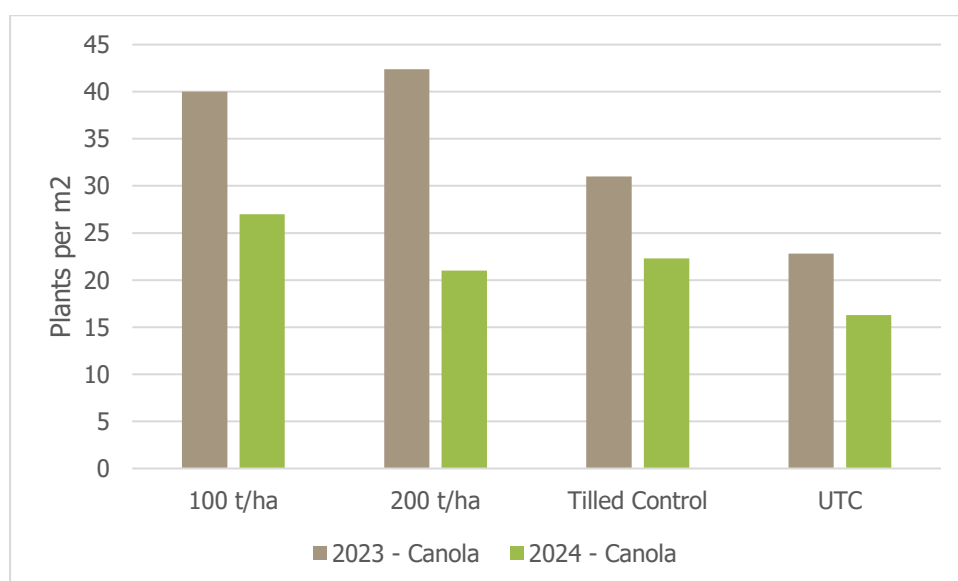


Figure 9: Average plant establishment counts across each treatment at the Woogenellup site, 2023 & 2024.

Scotts Brook (2)

At the second Scotts Brook trial site, there was no significant impact of claying, or incorporation only on canola (2023) or barley (2024) plant establishment (Figure 10). In both 2023 and 2024, the paddock was dry sown and there was relatively even emergence after significant June rainfall was received in each year. The heavy rainfall negated impact of non-wetting, whereas a more marginal break to the season, may have showed better results.

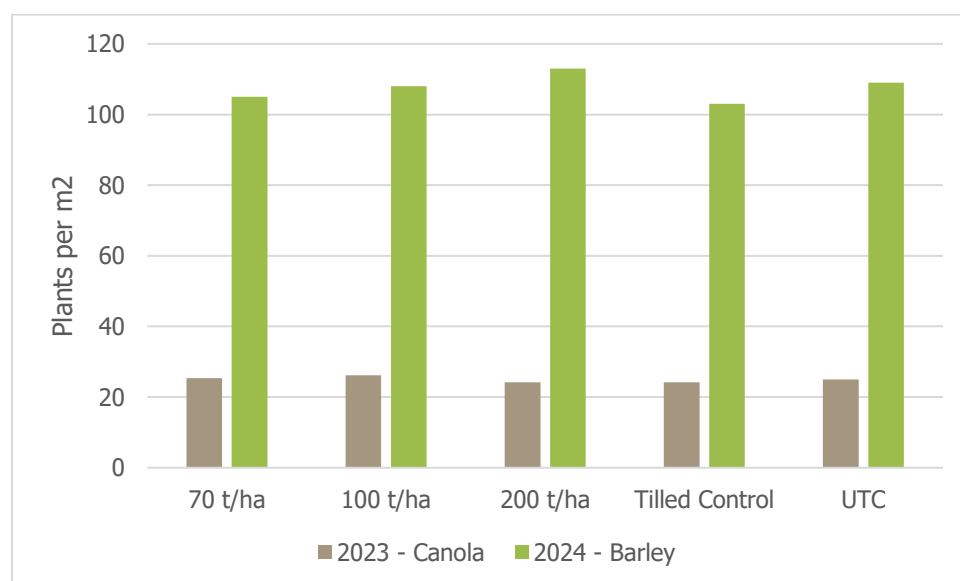


Figure 10: Average plant establishment counts across each treatment at the Scotts Brook site, 2023 & 2024.

NDVI Readings

Kojaneerup South

For the Kojaneerup South trial, NDVI was recorded by GreenSeeker in 2022, by satellite in 2023 and by multispectral drone (UAV) in 2024 (Figure 11). The NDVI values show plant health was highest in the 300 t/ha treatment in 2022 and then relatively even across treatments in 2023 and 2024.

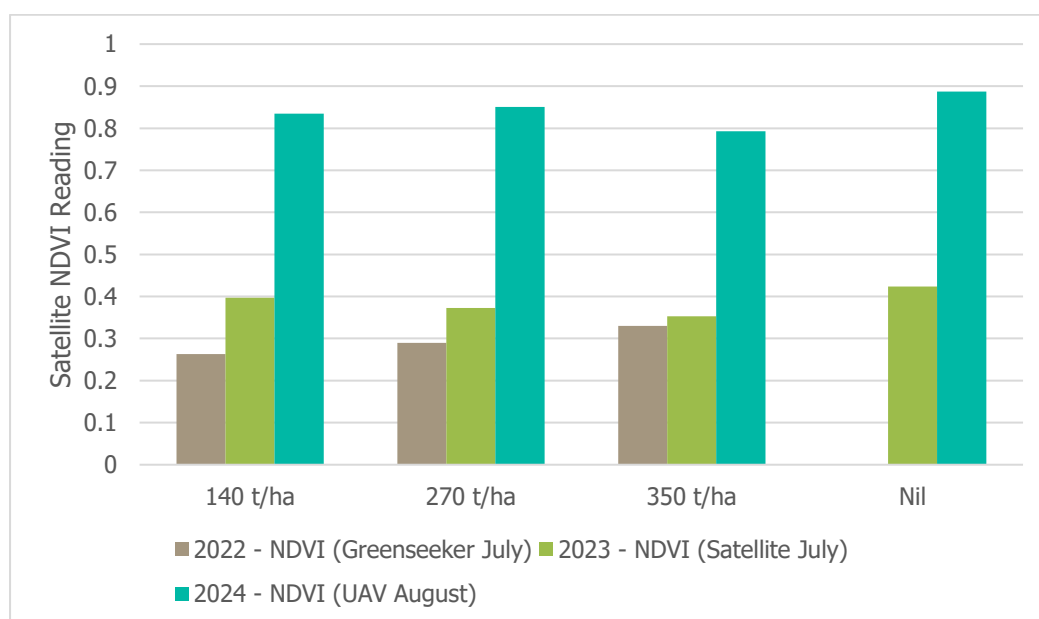


Figure 11: Average NDVI readings across each treatment at the Kojaneerup South trial site, 2022 – 2023.

Scotts Brook (1)

The NDVI readings taken for the initial Scotts Brook (1) trial site via satellite show plant health to be relatively even across all treatments in 2022, 2023 and 2024 (Figure 12). There is a slightly lower reading in 2023 in the UTC compared to the other treatments.

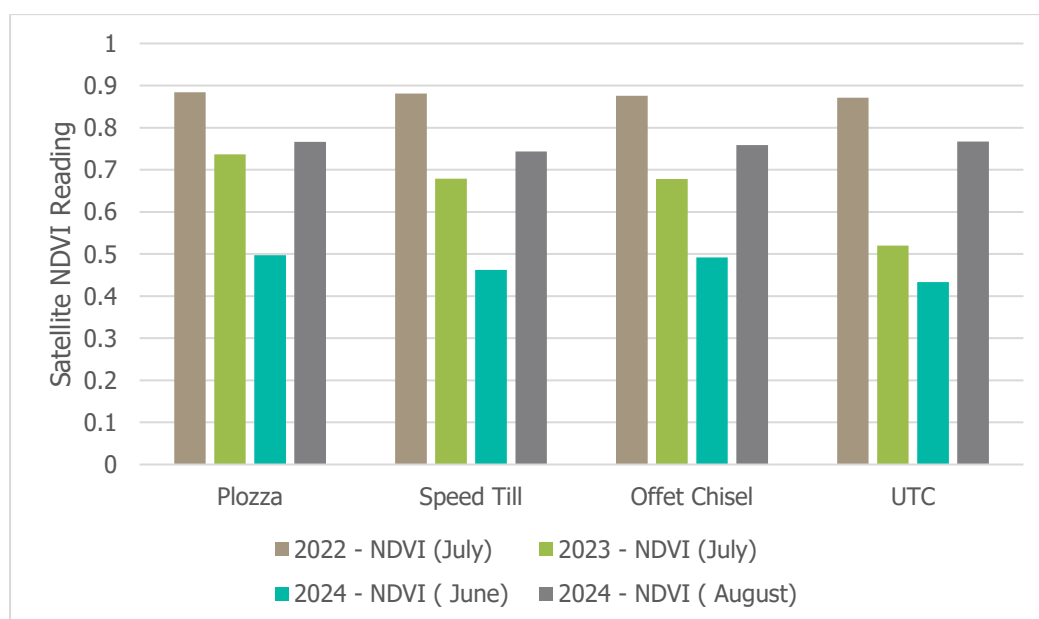


Figure 12: Average NDVI readings across each treatment at the initial Scotts Brook (1) trial site, 2022 – 2023.

Woogenellup

NDVI readings taken via satellite in 2023 and via UAV in 2024 for the Woogenellup site indicate that plant health was improved in the 200 t/ha treatment in comparison to the other treatments (Figure 13).

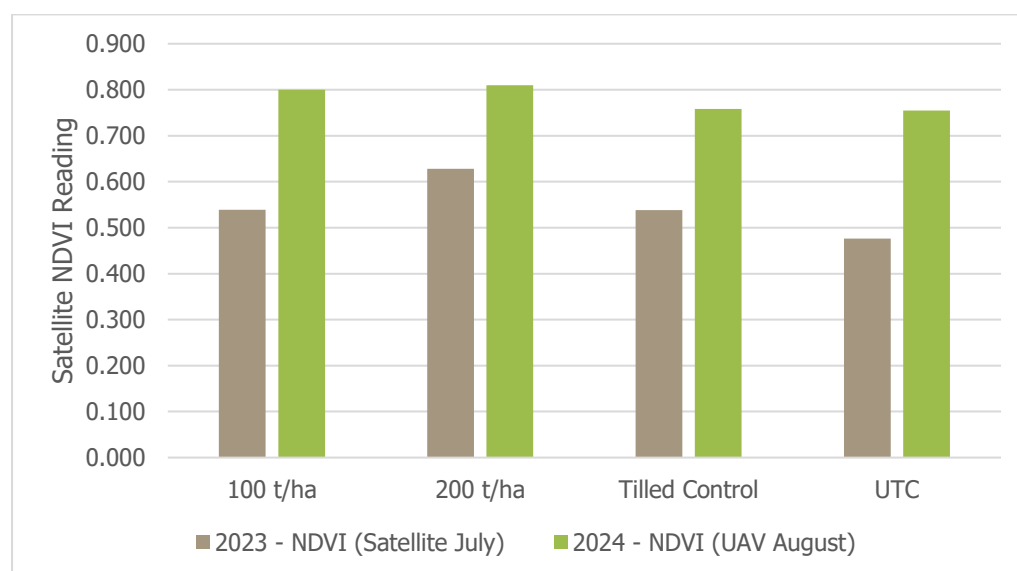


Figure 13: Average NDVI readings across each treatment at the Woogenellup trial site, 2023 – 2024.

Scotts Brook (2)

NDVI readings taken via satellite in 2023 and via UAV in 2024 across the second Scotts Brook trial site indicate that plant health was improved in the 70 t/ha and 100 t/ha treatments and significantly lower in the UTC treatment in 2023 but then very even across treatments in 2024 (Figure 14).

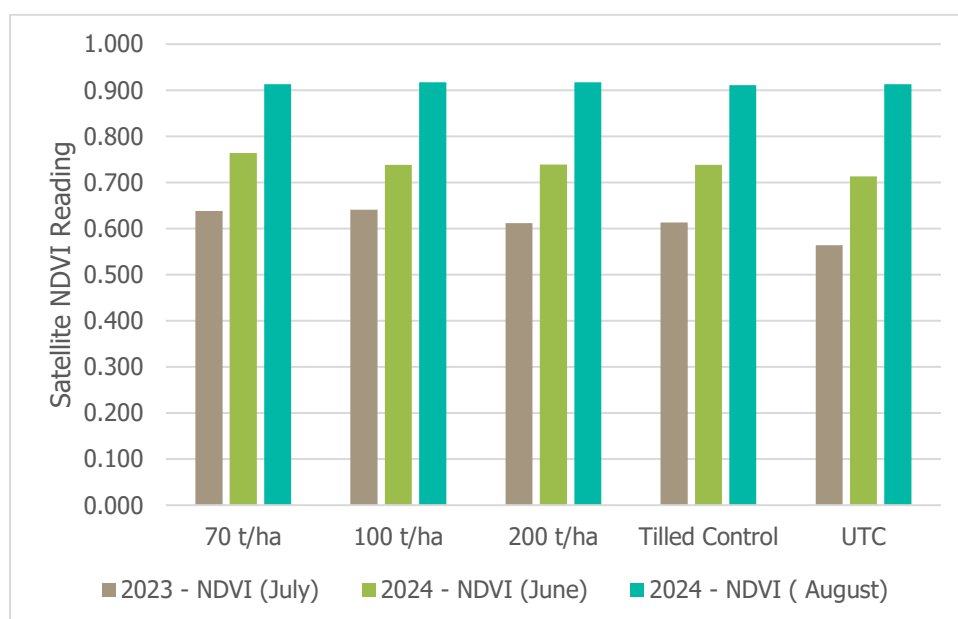


Figure 14: Average NDVI readings across each treatment at the second Scotts Brook (2) trial site, 2022 – 2023.

Grain Yield Results

Kojaneerup South

Grain yield results from the Woogenellup trial site, between 2022 and 2024 are shown in Figure 15 and Table 10. In year one of the trial there was a significant influence of clay rate on grain yield, particularly between the 140 t/ha and 270 t/ha treatments. Interestingly, the 140 t/ha clay rate failed to increase the soil clay content to above 5% (as is recommended). In years two and three, the grain yield differences between the treatments were less, indicating that, at the very least, the 350 t/ha rate was potentially not economical given lack of yield benefits.

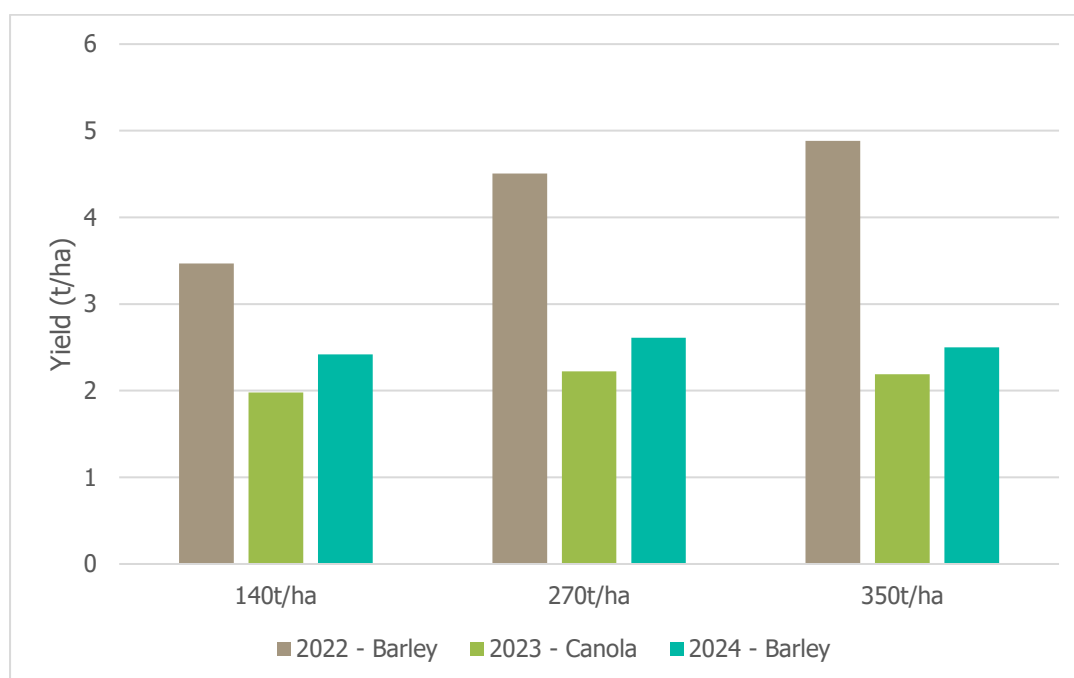


Figure 15: Average yields (t/ha) in response to clay treatments at the Kojaneerup South trial site, 2022 – 2024.

Table 10: Cumulative yield 2022-2024, barley – canola – barley, recorded at Kojaneerup South trial site in response to clay treatment.

Treatment	Cumulative Yield
140t/ha	7.854
270t/ha	9.334
350t/ha	9.575
UTC	7.61

Scotts Brook (1)

Grain yield results for the initial Scotts Brook (1) trial site, between 2022 and 2024, are shown in Figure 16 and Table 11. The results show that clay incorporation with plozza plough had a yield benefit in all years of the trial in comparison to the other treatments, especially when compared to the UTC. However, this yield benefit decreased in the second and third years, indicating that this yield benefit was most likely due to tillage, rather than an effect of the clay treatment (same rate across all incorporation methods).

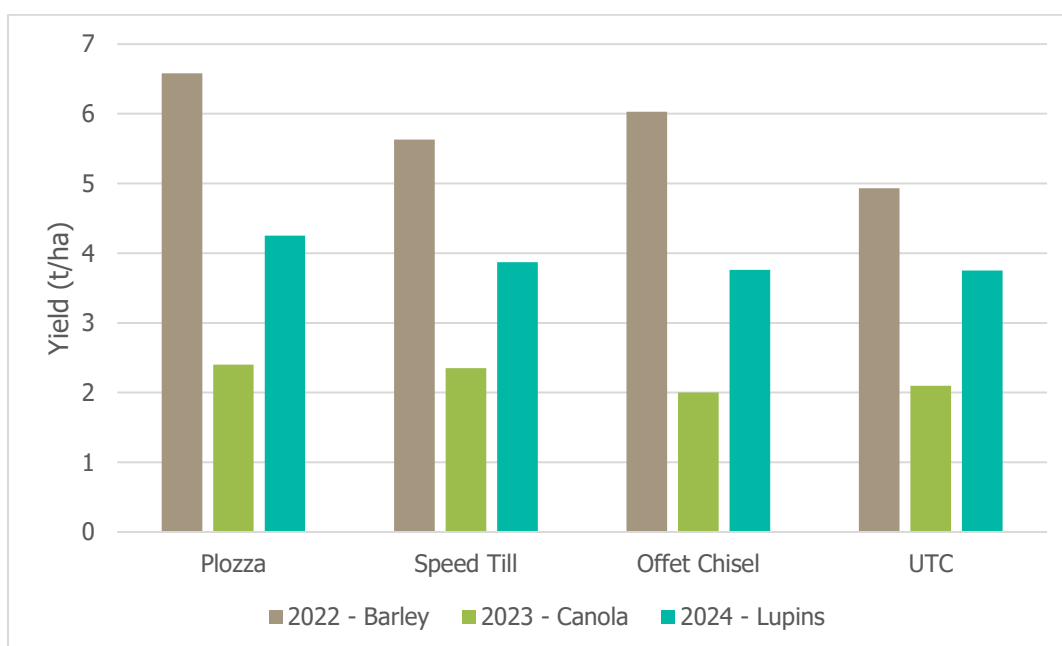


Figure 16: Average yields (t/ha) in response to clay incorporation treatments at the initial Scotts Brook (1) trial site, 2022 – 2024.

Table 11: Cumulative yield 2022-2024, barley – canola – lupins, recorded at the Scotts Brook (1) trial site in response to clay incorporation treatment.

Treatment	Cumulative Yield
Plozza	13.09
Offset Plough	11.395
Speed Tiller	12.025
UTC	10.8

Woogenellup

Grain yield results for the Woogenellup trial site, for 2023 and 2024, are shown in Figure 17 and Table 12. The yield results show a significant positive impact of claying compared to the UTC treatment. The 200 t/ha (incorporated by speed tiller) was the best performing treatment in both years indicating that although there is gravel in the soil (effectively reducing the soil content that needed to be ameliorated for non-wetting), a higher rate in this case was still necessary to achieve yield results. It was initially thought that clay rates could be pulled back in gravel soils due to the reduced soil content. The results also show that the tillage still had an impact into year two of the trial, with this treatment yielding significantly higher than the UTC in 2024.

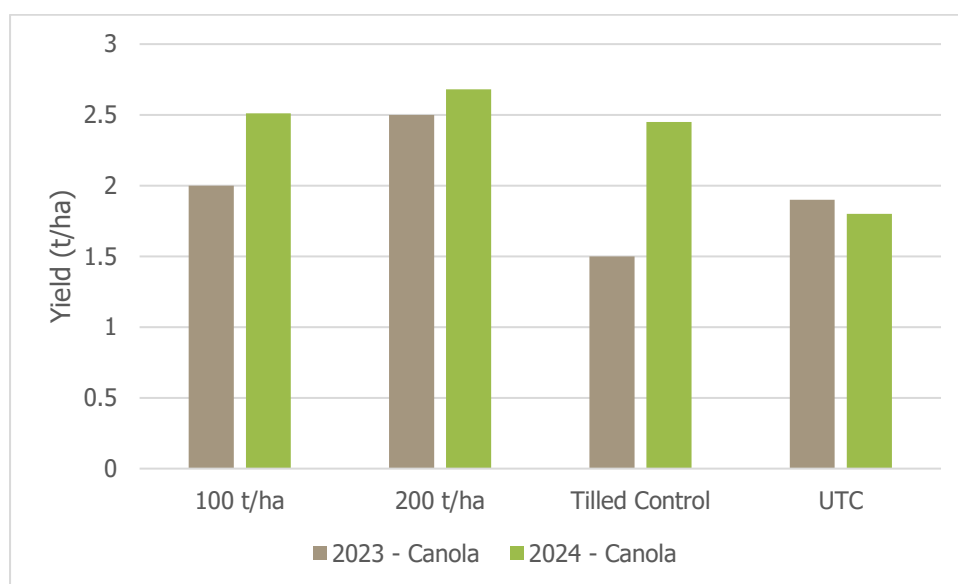


Figure 17: Average yields (t/ha) in response to clay treatments at the Woogenellup trial site, 2023 – 2024.

Table 12: Cumulative grain yield 2023-2024, Canola – Canola, recorded at the Woogenellup trial site in response to clay treatment.

Treatment	Cumulative Yield
100t/ha	4.51t/ha
200t/ha	5.18t/ha
Tilled control	3.95t/ha
UTC	3.7t/ha

Scotts Brook (2)

The grain yield results for the second Scotts Brook site for 2023 and 2024 are shown in Figure 18 and Table 13. These results show that both claying (with incorporation via tillage) and tillage (standalone) did not have a positive influence on year across both years of the trial. In both years, the Scotts Brook site was seeded into very dry conditions which were then followed by periods of heavy rainfall. This effectively meant that the impacts of non-wetting could not be tested with each clay and/or tillage treatment. Given claying of forest gravels is a novel practice, it would be very interesting to continue to monitor the impacts of clay treatments at this site.

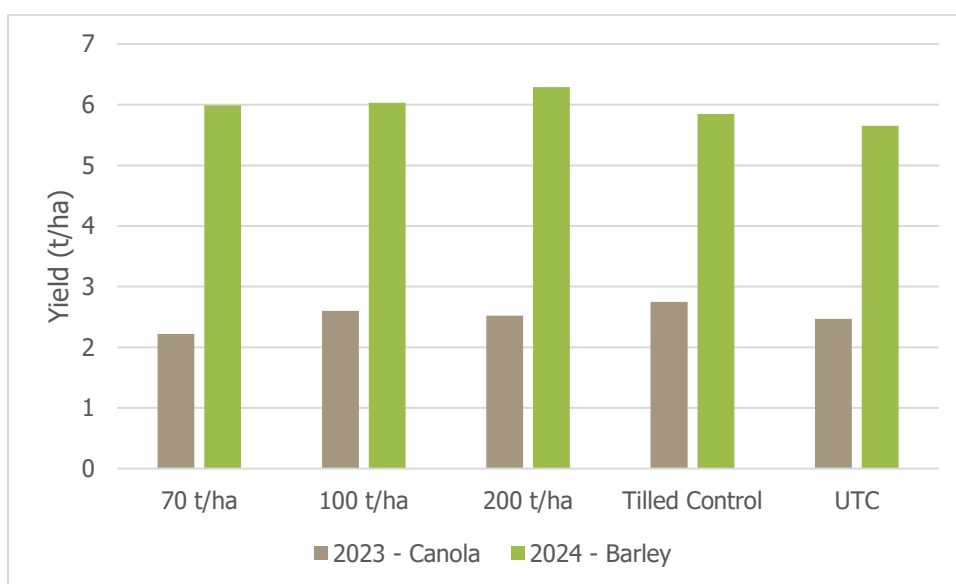


Figure 18: Average yields (t/ha) in response to clay treatments at the second Scotts Brook (2) trial site, 2023 – 2024.

Table 13: Cumulative grain yield 2023-2024, canola – barley, recorded at the Scotts Brook (2) trial site in response to clay treatment.

Treatment	Cumulative Yield
70t/ha	8.209
100t/ha	8.631
200t/ha	8.813
Tilled Control	8.6
UTC	8.12

Grain Quality

Grain quality data was collected in 2022 for Kojaneerup South and the initial Scotts Brook trial site, in 2023 for the Kojaneerup South and Woogenellup trials sites and in 2024, for the two Scotts Brook trial sites.

Kojaneerup South

At the Kojaneerup South trial, there was a marginal increase in protein and grain weight for the barley grown in year one on clayed treatments compared to the UTC treatment (Table 14). In year two of the trial (canola), there was no significant impact of clay on seed quality. The results highlight the potential for increased nutrition available (clay as a potassium and sulfur source) in the first year post claying.

Table 14: Barley grain quality data in response to each of the clay treatments at the Kojaneerup South trial site, 2022.

Clay Treatment	Moisture %	Protein %	Grain Weight (grams)
140t/ha	13.1	9.1	333.23
270t/ha	12.7	9.2	335.65
350t/ha	12.7	9.1	328.37
Control	12.6	8.8	320.65

Table 15: Canola seed quality data in response to each of the clay treatments at the Kojaneerup South trial site, 2023.

Clay Treatment	Moisture %	Protein %	Oil %
140t/ha	13.1	21.2	44.3
270t/ha	12.7	20.06	43.8
350t/ha	12.7	20.21	44.4
Control	12.6	22.1	45.1

Scotts Brook (1)

Grain quality results for the initial Scotts Brook (1) trial site show that in 2022, the plozza plough clay incorporation treatment has a significantly positive impact on grain protein, 9.9% compared to 9.1% in the UTC treatment (Table 16). When grain quality was again investigated in 2024 (two years later) for the same trial, lupin protein was still highest in the plozza plough treatment, but also the speed tiller treatment (Table 17).

Table 16: Barley grain quality data in response to each of the clay treatments at the Scotts Brook (1) trial site, 2022.

Clay Treatment	Moisture %	Protein %	Grain Weight (grams)
Control	12	9.1	328
Plozza	12.2	9.9	315
Offset Plough	12.2	9.3	320
Speed Tiller	12.1	9.1	335

Table 17: Lupin grain quality data in response to each of the clay treatments at the Scotts Brook (1) trial site, 2024.

Clay Treatment	Moisture %	Protein %	Grain Weight
Control	11.3	10.2	76.56
Plozza	11.2	11	80.4
Offset Plough	11.1	10.6	78.43
Speed Tiller	11.5	11	79.031

Woogenellup

Seed quality data recorded in the 2023 trial season at Woogenellup shows that clay rate did not have an influence on seed % oil content when compared to the UTC treatment (Table 18). The tilled control (tilled only) had a slightly higher oil content compared to all other treatments.

Table 18: Canola seed quality data in response to each of the clay treatments at the Woogenellup trial site, 2023.

Clay Treatment	Moisture %	Protein %	Oil %
Control	6.9	21.4	44.4
200t/ha	6.0	21.6	44.6
100t/ha	5.6	21.9	45.8
Tilled Control	5.8	20.6	47.4

Scotts Brook (2)

The grain quality data for the second Scotts Brook (2) trial site show that claying and tillage did not increase grain protein in barley (Table 19). In fact, the highest protein levels were recorded in the UTC treatment, as well as higher grain weight.

Table 19: Barley grain quality data in response to each of the clay treatments at the Scotts Brook (2) trial site, 2024.

Clay Treatment	Moisture %	Protein %	Grain Weight (kg/hl)
Control	10.6	12.7	63.03
70t/ha	10.4	10.4	60.053
100t/ha	10.9	11.1	61.24
200t/ha	10.8	11	62.202
Tilled Control	10.4	12.3	60.754

DISCUSSION OF RESULTS

Claying has been shown to be a highly effective amelioration technique on the non-wetting sands of the South Coast of WA. The aim has been to achieve at a clay content of at least 5% in the topsoil (0-10/15cm) to eliminate non wetting in soils (with low organic matter). Up until recent years, machinery constraints have meant that the 5% threshold was easily surpassed due to clay being applied at typically higher than needed rates. While this has been largely effective, it has also come at a large expense. With the aim of the project to demonstrate claying practice efficiencies that could be achieved (with gravel in mind too), a number of trial sites were implemented across the Albany Port Zone between 2022 and 2024. Here's what we found.

Kojaneerup South

The Kojaneerup South trial site was established in 2022 to investigate a range of different clay rates on a sandy (low organic matter duplex), common to the South Coast. The clay rate treatments applied aimed to achieve:

- Just under the 5% clay content threshold. The final clay content was 3.8% in the 140 t/ha clay rate treatment (incorporated to 15cm).
- Hit the 5% clay content. The final clay content in this treatment was 5.8% (270 t/ha incorporated to 15cm),
- Over-achieved on clay content. This was the 350 t/ha clay treatment also incorporated to 15cm, where the final clay content was 7%.

The MED non-wetting test results showed that both the medium and high rates of clay completed alleviated non-wetting, while the lower rate still showed some non-wetting characteristics. Plant establishment was higher as the clay rate increased across all three years of the trial.

NDVI readings were fairly inconclusive, however yield results, particularly in the first year (2022) really highlighted the benefits of getting the clay rate right. The largest jump in yield in 2022 was between the low and medium clay rate treatments, most likely due to the medium treatment achieving that 5% clay content threshold. The yield increases from the medium to high clay rates was less and shows it is not economical to spread more clay once the 5% threshold has been achieved. Given the spreader used in the trial held approximately 40t of clay, this would equate to a saving of two additional passes per ha of paddock clayed, at a cost of approximately \$125/ha. The yield results in 2023 and 2024 showed less of an impact between clay rates but it should be noted that both years were extremely dry with crops being sown dry and germinated after significant June rainfall (non-wetting less of an issue in these years).

Scotts Brook (1)

The first Scotts Brook (1) trial site was also established in 2022. As a point of difference, this trial was established on a forest gravel and rather than investigating clay rates, the trial investigated best clay incorporation method for a gravel soil. The ability to properly incorporate a high rate of

clay into gravel soils is significantly more difficult than it is on sandy soils. This is largely due to difficulty in soil mixing, due to the gravel high gravel percentage.

In this trial the clay rate spread was standard across the site (400 t/ha) and applied with a CAT scraper. The incorporation treatments were as follows:

- Plozza plough to a depth of 30cm, resulting in a final clay content of 6.5%
- Offset chisel plough to a depth of 15cm, resulting in a final clay content of 8.6%
- Speed tiller to a depth of 10cm, resulting in a final clay content of 10.7%

The plozza plough effectively mixed the soil due to its inversion technique, however, the offset chisel plough struggled to penetrate the gravel and mix the clay. This resulted in a clay capping effect of the surface of the soil.

The end clay content % for each treatment was a good demonstration of the dilution effect when incorporation depth is considered. The greater the incorporation depth, the higher the dilution of the clay, hence the plozza plough with the deeper incorporation method, had a significantly lower final clay content.

MED testing showed that the 400 t/ha of clay competed alleviated non-wetting soil characteristics. Plant establishment in year one (2022) was significantly higher in the plozza plough treatment compared to the others and NDVI and harvest yield in 2022 showed a similar result. Although yields were highest in the plozza plough treatment in 2023 and 2024, this was less pronounced, indicating that potentially the tillage effect of the type of incorporation was playing a larger role in yield initially than the clay and that the effect of the clay on yield was negligible (no significant differences between UTC and clay treatments). Again, this may also have been season related, with crops sown dry in 2023 and 2024 and then germinating on significant June rainfall. Given claying of forest gravels is relatively novel, there would be merit in continuing to monitor this site.

Wetting agents have typically been used on forest gravels, mostly successfully, however, at a cost of up to \$45/ha annually, a permanent fix (in claying) may prove cost effective in the long run.

Woogenellup

The trial site implemented in Woogenellup in 2023, aimed to further investigate claying of gravel soils with the hypothesis that less clay is required to ameliorate non-wetting in a gravel soil due to a lower overall soil content. The site was a gravelly sand (but not a forest gravel), with this soil type also very typical of the South Coast and lower Great Southern region. The gravel content ranged from 20 – 35%. The treatments were as follows:

- 100 t/ha incorporated to 10cm resulting in a final clay content of 3.9% (gravel removed)
- 200 t/ha incorporated to 10cm resulting in a final clay content of 5.9% (gravel removed)
- Tilled only (control)
- UTC

The lower clay rate failed to reach the 5% soil clay content threshold even with gravel removed from the sample. The 200 t/ha treatment was spot on by achieving just over the 5%. Interestingly the MED results showed the lower rate to be no longer non-wetting, while there was some non-wetting characteristics (MED score 1) in the higher rate. This was perhaps a sampling error.

Overall tillage (not clay content) slightly reduced the soil strength compared to the UTC, however, soil strength was difficult to measure given the gravel in the soil. Plant establishment was higher in the higher clay treatment in year one (2023), however this was less so in 2024 (most likely as a result of the season). NDVI readings were highest for the higher clay rate and it was the same for yield. The 200 t/ha clay rate treatment resulted in the highest yield in both years, showing there was benefit in achieving the 5% clay content in soil. All clay and tillage treatments outyielded the UTC treatment in both years.

This trial showed that in gravelly sands, it is still important to clay with a rate that will achieve 5% clay content in the topsoil. The trial also showed that strategic tillage can also have a positive impact on yield, into a second season too. It would be interesting to monitor further to determine when the tillage loses its effectiveness on crop yields and how/if claying treatments continue to yield better over time.

Scotts Brook (2)

The second trial implemented at Scotts Brook (2), aimed to determine if clay rates could be reduced in forest gravels due to the gravel content reducing the soil content requiring amelioration for non-wetting. Although these soils are highly repulsive and traditionally struggle with plant establishment, the high organic matter content (typically >3.5%) that is common in these soils makes it very difficult to determine the rate of clay that would be required to alleviate the non-wetting. A further complication is that these soils usually already have relatively high clay contents as well as the highly variable gravel percentages. This possibly makes determining a “rule of thumb” or target (post amelioration) clay percentage difficult.

The trial site had a high gravel content (by weight) of 65-75% but also had a high organic matter content of 3.68%. In 2023 the following treatments were implemented to explore this:

- 70 t/ha clay incorporated to 15cm resulting in a clay content of 7.84%
- 100 t/ha clay incorporated to 15cm resulting in a clay content of 8.26%
- 200 t/ha clay incorporated to 15cm resulting in a clay content of 9.8%
- Tilled only control (to 15cm)
- UTC

Given the starting soil clay content (prior to amelioration) was 4.8%, it was not surprising that all the clay treatments increased soil clay content to well above 5%. MED testing conducted for the 100 t/ha treatment showed that non-wetting was completely alleviated with an initial score of 2 reduced to 0.

Unfortunately, there was no significant impact of the claying or tillage on plant establishment counts, yield or grain quality across the two years of the trial. Again, it should be noted that

there were two dry starts to the growing season in 2023 and 2024 and the trial was sown dry in both years. This was followed by significant rainfall in June (particularly in 2024).

With seasonal conditions not being conducive to the testing of non-wetting, and the cost of wetter application year-in-year-out, it would be very interesting to continue to monitor the ongoing impacts of the clay treatments at this site. Given the permanent nature of claying, it is highly likely that even in the marginal yield gains would eventually pay off over time. However, it should be noted that strategic tillage may also be cost-effective amelioration strategy in these soils.

CONCLUSION

This project has demonstrated that claying remains a highly effective strategy for alleviating non-wetting in sandy and gravelly sandy soils of the South Coast of WA. Across four trial sites established between 2022 and 2024, key findings highlight that:

- Achieving a topsoil clay content of at least 5% is critical for effectively eliminating non-wetting in low organic matter sands and sandy gravels.
- Forest gravel soils require careful consideration of incorporation depth and mixing ability, with insufficient incorporation leading to clay 'capping' at the surface.
- Lower clay rates may be viable in gravel-rich, low organic matter soils due to the reduced proportion of ameliorable sand, but achieving the 5% clay threshold is still essential for consistent yield benefit. The jury is still out on clay rates for high organic matter gravelly soils (forest gravels) and more monitoring is recommended.
- It appeared that tillage (particularly by plover plough) provided short-term improvements in crop establishment and yield on forest gravels but was generally less effective beyond the first season.
- Seasonal conditions, particularly the dry starts in 2023 and 2024, followed by significant June rainfall, influenced trial outcomes and masked some non-wetting treatment effects, reinforcing the value of long-term monitoring.

Overall, results support a more targeted and efficient approach to claying, tailored to soil type, clay quality and incorporation method so that the agronomic and economic outcomes are maximised for growers in the South Coast and Great Southern regions of WA.

IMPLICATIONS

The project confirms that achieving around 5% clay content in the topsoil is an effective and economical target for alleviating non-wetting in sandy and gravelly sandy soils. Clay rates above this provide limited additional economic benefit. Incorporation method and soil type, particularly gravel content, significantly influence outcomes. In forest gravels, it appears that strategic tillage alone can offer short-term improvements, but if further monitoring of claying in these soil types shows yield benefits over time, then this remains a durable solution, especially when compared to the year-in-year-out costs of soil wetter applications.

RECOMMENDATIONS

Further research should explore the long-term impacts of claying on forest gravel soils, where results to date remain inconclusive due to seasonal conditions and existing soil complexity (gravel content & organic matter content). Investigating the interaction between clay rates, gravel content, and organic matter levels would help determine the effectiveness of claying in these soils and refine guidelines if long term productivity benefits are shown. Additionally, research into alternative incorporation methods suited to gravelly soil profiles could improve clay mixing effectiveness and reduce costs. Long-term monitoring of these existing trial sites (particularly the Scotts Brook trials) is recommended to assess establishment and yield benefits over time and persistence of these benefits. An accompanying economic analysis would assist growers to better weigh up the costs/benefits of non-wetting amelioration strategies (i.e., wetters, tillage, claying).

GLOSSARY AND ACRONYMS

Below is a sample abbreviations and acronyms list. Be sure to include all abbreviations and acronyms that appear in the report.

OM	Organic Matter
MED	Molarity of Ethanol Droplet (test)
NDVI	Normalised Difference Vegetation Index (measure of vegetation health)
UTC	Untreated control

REFERENCES

Nil

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