Identifying strategies to address rainfall infiltration and soil constraints in FNQ soils

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Key words

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Take home messages

- Improving rainfall infiltration can increase average yield and reduce crop failure risk in droughted seasons
- Solutions for improving soil surface infiltration are known but:
  - Benefits are inconsistent across soil types, especially those with sub-soil constraints.
  - Adapting these solutions to economically viable commercial farms is challenging.
- Banding locally available soil amendments along the seed trench was identified as the best-fit option and tested on-farm
- Variability in the trial site masked treatment effects on crop establishment, but amendments consistently reduced soil crusting
- Banded soil amendments are likely to improve crop establishment, water use efficiency, and yield where soil crusting causes establishment losses.

One challenge for growers in Far North Queensland is to capture high intensity rainfall and conserve it between rainfall events in our highly weathered soils, without losing nutrients or topsoil from the system. Funded research has provided an opportunity to adapt known water conserving technologies and practices into the Far North Queensland cropping systems.

A large majority of soils across this region are inherently low in clay and carbon content and quite often have very degraded soil surfaces because of years of intense weathering. This quite often leads to intrinsically poor soil surface hydrology characteristics such as poor structure and infiltration and/or subsoil constraints such as hard-setting and poor drainage. These constraints are all too frequently exacerbated by heavy tillage practices. Poor soil hydraulic characteristics restrict plant root growth deep into the soil profile often resulting in early onset of terminal drought stress despite adequate rainfall occurring during the cropping period.

Increasing the proportion of rainfall (and irrigation) transpired by crops and converted into yield is fundamental to improving northern cropping systems and managing both crop and fodder production risks. To do this we first must identify and understand these soil constraints and what strategies are available for their remediation. Soil amendments applied to the surface and incorporated can positively change the soil through increasing soil carbon and cation saturation resulting in reduced soil tensile strength and the potential for soil crusting.

Background

Many practices and technologies have been shown to reduce soil surface constraints and improve rainfall infiltration, but benefits are inconsistent across soil types, especially if co-located with sub-soil constraints including temporary waterlogging. Adapting these solutions to economically viable commercial farms remains elusive.

Soils within broadacre cropping areas of Northern Australia have intrinsically poor hydrology characteristics due to the soils' parent material, climate and the degree of weathering. The combination of intrinsically poor soil structure with heavy monsoonal/wet season rain events and cultivation practices has led to a rapid decline in soil organic matter on soils already low in organic matter. Poor subsoil structure exacerbated by heavy tillage can also result in temporary waterlogging or becoming impervious to plant roots, both limiting plant access to water that does infiltrate into the soil.

Banding locally available soil amendments along the seed trench was identified as the best-fit option by collaborators and tested on-farm. In theory, the cost-efficient amendment band initially buffers the seedbed from extreme temperatures, reduces evaporation, prevents soil crusting, and maintains soil structure needed for infiltration, by protecting the surface soil from rainfall impact in a narrow band above the seed. The subsequently improved seedbed conditions support rapid and uniform crop canopy closure, which protects the soil across the entire inter-row space from rainfall impact and evaporation. Additional crop root proliferation through the moist topsoil improves soil macro-pores, and dead roots create channels for rain to infiltrate and drain in subsequent crop phases, i.e., improved hydrological properties.

Trial site overview

In the 2023-24 wet season, a trial site at Dimbulah (17.123; 145.137) was chosen due to the light sandy-loam soil texture and high potential for soil hydrology constraints, particularly due to surface crusting. Initial soil test results showed very low soil organic matter levels of 0.39% and low CEC of 2.5 cmol+/kg in the top 30cm of the soil profile.

Soil amendments were applied on top of the cultivated seed bed followed by shallow incorporation prior to sowing cotton. Due to the cost of applying effective quantities of amendments, it was decided to band products over the plant rows (similar to the cane industry) as well as focus on locally available products such as mill mud and compost.

Treatments included prilled gypsum (6t/ha), mill mud (50t/ha), compost (50t/ha), crushed basalt (15t/ha), a luxury treatment combining all four soil amendments and a cane mulch treatment (approximately 5t/ha) representing crop residue retention. Application rates were calculated based on a 30cm wide treatment band and plot lengths of 6 metres
i.e. weight of amendment ÷ (plot length x band width x rows).

Unseasonal rainfall (a result of cyclone Jasper) led to the site being replanted at a lower population over the top of the original planting (time of sowing (TOS) 1), however this second planting (TOS 2) also encountered waterlogging due to a second cyclone rain event. Crop establishment data and surface tension readings were taken throughout the season. Due to the variability of crop growth because of the split planting and the main focus initially being soil improvement, no yield data was taken.

A deep penetrometer was used mid-season to evaluate moisture penetration and rooting ability of the crop where it was discovered that a significant hard-setting layer was present.

Results

Crop establishment was more variable across the site than between treatments due to the unseasonal cyclone which led to significant waterlogging and soil crusting resulting in a variable plant population in the first time of sowing (TOS). The site was over sown with a second planting at a lower rate to ensure adequate plant population. However, it too experienced a severe waterlogging event from a second cyclone-based rainfall event.

Crop establishment in the first TOS varied between 4.0–5.4 plants/metre with the untreated control having an established population of 4.9 plants/metre. In the second TOS, the retained cane mulch had the lowest establishment with 3.6 plants/metre compared to the other treatments which varied from 4.1–4.9 plants/metre (Figure 1). Overall, the prilled gypsum treatment had the highest combined established plant population at 10.3 plants/meter with the mill mud, crushed basalt and luxury treatments being comparable to the untreated control in final plant population, being 9.4, 9.3, 9.1 and 9.5 plants/metre respectively. Compost treatment had slightly lower populations at 8.6 being just higher than retained cane mulch at 7.8 plants/metre.

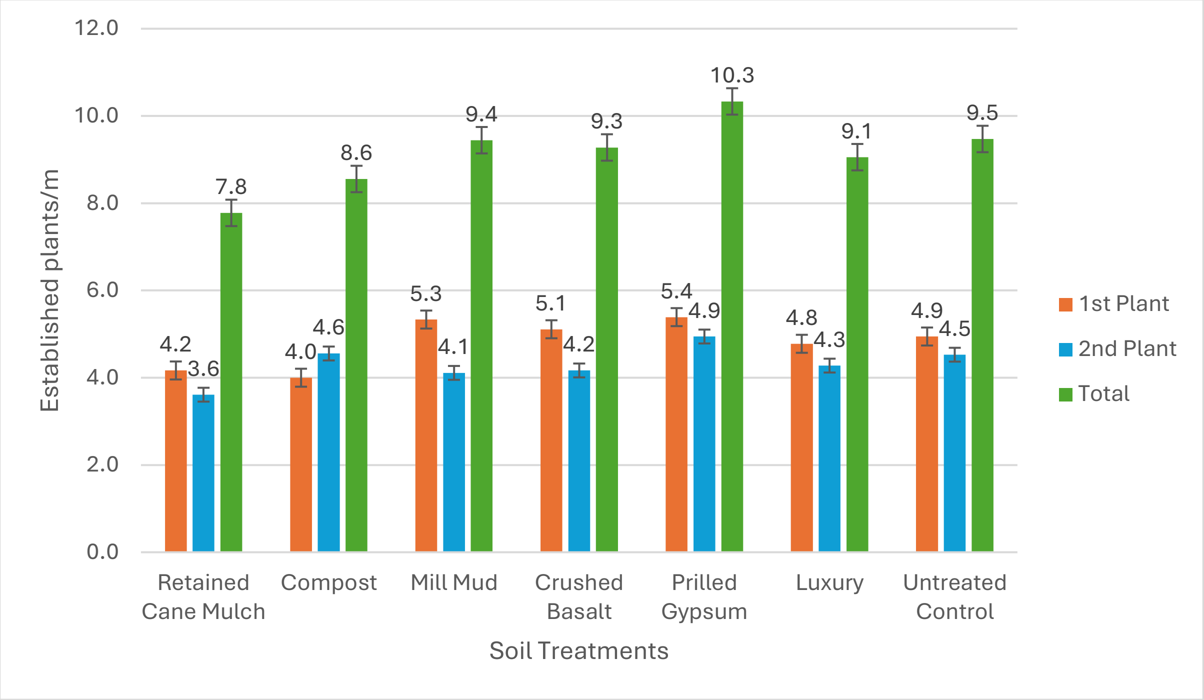

Figure 1. The effect of surface applied soil amendments on mean cotton plants established N=3.

All soil amendment treatments reduced soil tensile strength at all three sampling dates (Figure 2). Retained cane mulch provided the quickest reduction in tensile strength, a level that was then stable during the course of the trial and only slightly improved upon as the season progressed. By 120 days after application (DAA), all treatments (excluding the retained cane mulch) continued to improve upon the initial results obtained at 80 DAA, however by 180 DAA at the end of the crop the treatments had equalised. It was noted however that the untreated control (UTC) continued to reduce in tensile strength. This was attributed to protection of the soil surface from weathering by the expanded crop canopy and the soil surface being continually kept wet via irrigation. This constant soil moisture level prevented the soil from forming a crust upon drying, thereby reducing its tensile strength.

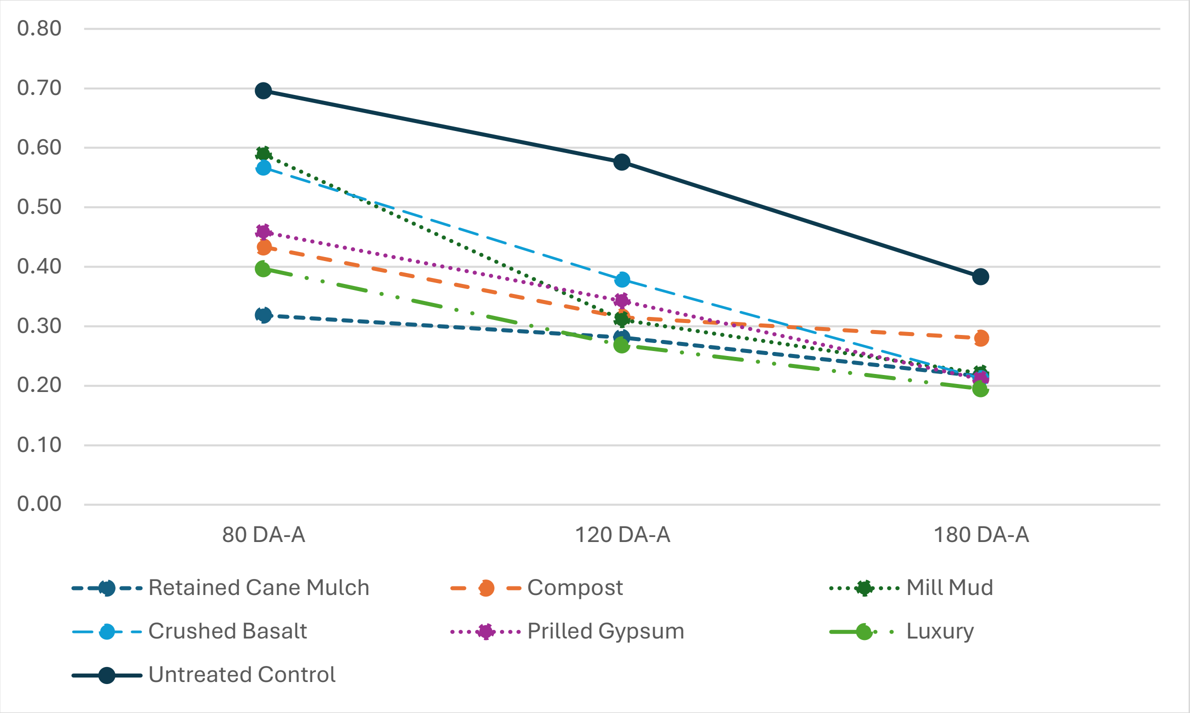

Figure 2. Measured soil resistance post-amendment application

Soil samples were collected at harvest to a depth of 10cm from each plot to investigate how the amendments had changed any soil surface characteristics. The addition of soil amendments was shown to have a positive effect on soil pH changing it from 5.7 in the UTC to 6.6 in the compost and mill mud treatments to over 7 in the gypsum and luxury treatments whilst cane mulch and crushed basalt had minimal to no effect. Treatments of mill mud, compost, luxury and retained cane mulch all showed a net increase in organic carbon levels (24%, 31%, 19% and 23% greater than untreated control, respectively) whilst gypsum and crushed basalt remained unchanged. It must be noted however that the results can be confounded by the partial/aggregate size of the amendments for example mill mud having high proportion of clods. Compost and retained cane mulch treatments also had a 30% increase in active labile carbon content.

The addition of soil amendments was also found to reduce aluminium saturation percentage within the soil whilst significantly raising the soil calcium saturation levels. Gypsum application was seen to increase calcium levels to the point where they started to have a negative impact on other soil ions namely soil potassium saturation. Calcium to magnesium ratios were increased by all treatments when compared to the UTC and soil eCEC was also increased when compared to the UTC. An increase in CEC allows the soil to retain more nutrients and reduces the potential for leaching, however for most of the soil, the initial focus should be on increasing soil organic matter as this is the main limiting factor to soil structure.

Table 1. Observed soil characteristics at 0-10cm at harvest.

Treatment	Gypsum	Mill Mud	Compost	Cane Mulch	Crushed Basalt	Luxury	UTC
pH (H20)	7	6.6	6.6	6.2	5.8	7.4	5.7
Organic Carbon %	0.45	0.58	0.64	0.57	0.4	0.54	0.44
Active Carbon	212	236	292	296	180	279	207
K%	3.9	8.1	11.6	9.3	11.5	3.4	16.6
Ca%	91.4	71.2	68.2	71	61.8	91.2	50.3
Mg%	3.7	19	19	17.9	15.4	4.7	16.1
Al%	1	4.5	3.5	4.9	9.7	1	15.6
Na%	1.1	1.6	1.2	1.7	1.6	0.7	1.5
eCEC	4.9	2.9	3.4	2.7	2.3	5.9	2
Ca:Mg ratio	25	3.8	3.6	4	4	19.3	3.1

Conclusion

Variability across the trial site masked treatment effects on crop establishment, but amendments consistently reduced crusting (lowered soil surface tensile strength) during crop establishment. This means that banded soil amendments are likely to improve crop establishment, water use efficiency, and yield where soil crusting causes establishment losses.

There is a need to further adapt this potential solution to lower treatment costs, manage sub-soil constraints and the carbon cycling impacts on nitrogen availability to the establishing seedling.

Utilisation of crop residues (retained mulch treatment) provided the best/quickest response to reducing soil surface strength however it also had a negative effect on plant establishment. Establishment was affected by factors other than crusting associated with the unusually high December rainfall (cyclone Jasper) in which the large amount of retained residue constrained plant establishment. The addition of high organic carbon materials such as compost and mill mud could reduce soil surface crusting and provide an early nutrition benefit for the crop. All treatments continued to reduce soil resistance, however by the end of the season although still improved over the UTC, treatments had begun to equalize.

The cost of applying amendments in large enough quantities to change soil characteristics can be prohibitive with the simplest solution possibly being to maintain a suitable amount of crop residues and roots in the soil profile (i.e. no-till conservation agriculture practices). Incorporating cover cropping strategies to produce a purposeful crop residue in conjunction with no-till systems could also be employed to maintain the integrity of soil aggregates and porosity (soil structure).

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