Impacts of crop management strategies on nutrient stratification and soil test interpretation

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Key Findings

- Concentrated chaff distribution had no significant impacts on nutrient stratification either horizontally or vertically across the landscape at three sites.
- Chicken litter applications appear to compliment traditional chemical fertiliser applications by increasing P availability.
- All nutrients assessed were well above established critical levels and there was a tendency for all nutrients to be concentrated at the surface (0-5 cm) regardless of the known differences in mobility between N, P, K and S.

Why do the trial?

Nutrient stratification is where nutrients such as nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) occur naturally as layers or bands through the soil profile as a resulted of pedological processes or may occur through anthropogenic (man-made) processes. Nutrient stratification can significantly reduce grain production through limiting effective spatial and temporal synchronisation between soil nutrient supply and crop demand. Nutrient mobility in the soil can further magnify stratification. Mobile nutrients like N and S can move deeper into the profile leading to potential crop nutrient deficiencies in the topsoil where most plant roots are located, while immobile fertiliser nutrients like P and K tend to be concentrated in the top 10 to 15 cm.

In no-tillage systems, the lack of mixing means banded immobile nutrients become more stratified. This can be either in drill rows (horizontal) or by vertical concentration in surface or subsurface layers. The principal management issue from stratification is that current soil tests (0-10 cm) may not accurately reflect the potential response of the crop to applied fertiliser and so this becomes a significant issue to be accounted for when making agronomic decisions. Furthermore, mismatches between the location of roots and nutrients (and water) can significantly limit crop growth.

The aim of this study was to investigate two management strategies applicable to the Mid-North region that could influence nutrient stratification. These strategies include the concentration of harvest residues areas of the paddock and the application of chicken litter as an alternative or supplement to fertiliser programs.

How was it done?

The study involved sampling several field sites investigating nutrient distribution around concentrated chaff lines at sowing (n=3) and where growers have routinely applied chicken litter (n=3). Soil samples were taken prior to sowing and analysed for concentrations of N, P, K, S and carbon (C).

Chaff residue distribution with controlled traffic

Over the past decade, we have seen a shift in width of headers fronts, on average from 8-9 m to now 12 m. This means the chaff spread out the back of the header also needs to travel a greater distance to be spread evenly. In scenarios where the chaff is not spread evenly over consecutive years there is the potential for nutrients (particularly N, P, K & S) to become horizontally stratified across the soil surface as chaff residues can contain significant amounts of these nutrients. A common example is K deficiency identified through increased dry matter growth of crops sown over concentrated windrows.

Sites were located at Spalding, Hacklins Corner and Redhill in paddocks with long term controlled traffic. Site information collected included previous crop type and yield, fertiliser applications, harvester comb width, harvest date and number of years using guidance systems. Four cores were taken at each sampling point (Figure 1) with soil taken from each core separated into three depths (0-5 cm, 5-10 cm and 10-20 cm) and combined into one bulk sample for each sampling point and depth. Four replicates were taken at each site at 10 m intervals along the chaff line/harvester tracks. An example of chaff distribution at two sampling points is shown within Figure 2.

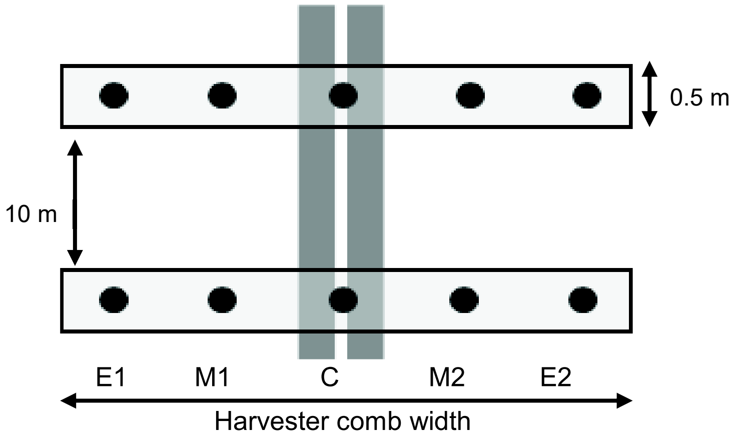

Figure 1. Sampling points along the width of a harvester comb. Four cores were taken per sampling point (E= end, M = middle and C = centre) with each sampling point a certain distance away from the chaff line.

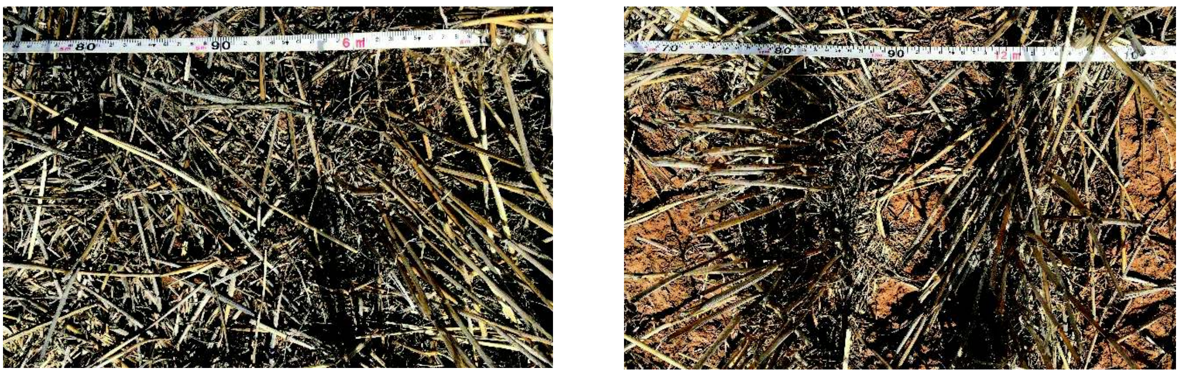

Figure 2. Chaff residue distribution at sampling point 'C' (left) and 'E1' (right) at the Redhill site.

Broadcast application of chicken litter

The use of chicken litter (CL) is a common nutrient source in the Mid-North to compliment traditional fertiliser programs. Chicken litter contains both macro and micro nutrients that can be beneficial to crop growth. Concentrations of these nutrients can vary between types and batches of CL. Most growers will usually spread CL on their whole farm using a three to four year rotation system and select a portion of their paddocks to be spread every year. Chicken litter is mostly commonly spread on the soil surface several weeks prior to seeding at a rate of 2.5 to 3 t/ha. The effect of nutrient accumulation at the soil surface may be amplified in systems that combine CL application with no-till seeding operations. This is due to the topsoil (~5 cm) being prone to drying which can reduce the availability of nutrients to the crop and therefore decrease plant uptake.

Three sites were chosen where a simple comparison of CL application vs normal fertiliser inputs could be achieved. One site (Marrabel) had an area within the paddock of no applied CL while the rest of the paddock had CL applications on top of a regular fertiliser program. The second site (Hill River) was simply a paired paddock comparison of no CL + fertiliser vs CL + fertiliser and the third (Hart) was a comparison of an area with applied CL vs a fence line sample. The authors note that it was not possible to account for differences between paddocks through different crop rotations and potentially different inputs at site two. Site information collected included number of CL applications, rate of CL application (Table 1), spreader type and width, type of CL and additional fertiliser. Eight different sampling points were taken within the paddock which had CL applied at depths of 0-5 cm, 5-10 cm and 10-20 cm.

Table 1. Chicken litter application details (t/ha) for all three sites.

Site location	Chicken litter application details
Marrabel	3 applications - 2009 2.0 t/ha, 2012 2.4 t/ha and 2014 3.0 t/ha
Hill River	5 applications of 2.0 to 2.5 t/ha over 10 years
Hart	3 applications - 2008 4.0 t/ha, 2009 3.4 t/ha and 2012 2.1 t/ha

Results and discussion

It should be noted that due to different sizes in increments the 0-5 cm and 5-10 cm layers cannot be directly compared with the 10-20 cm layer. In order to compare results with the 10-20 cm layer an average of the 0-5 cm and 5-10 cm layer must be determined.

Chaff residues

Across all three sites there was no significant effect ($P \leq 0.05$) of chaff lines on the distribution of nitrate (mg/kg) horizontally. The distribution of nitrate horizontally at the Spalding site is shown within figure 3. The concentration of nitrate in the 0-5 cm layer was significantly higher than the 5-10 cm layer at both the Spalding and Redhill sites indicating vertical stratification (Table 2). At the Hacklins Corner site vertical stratification of nitrate was not present between soil layers.

Table 2. Average nitrate concentration for all three sites. Where present, different letters denote significant differences ($P \leq 0.05$) between depths at the same site only.

Site	Depth	Nitrate NO_3 (mg/kg)
Spalding	0-5	60.0 ^{a}
	5-10	33.8 ^{b}
	10-20	20.3
	LSD ($P \leq 0.05$)	6.6
Redhill	0-5	58.1 ^{a}
	5-10	24.2 ^{b}
	10-20	20.1
	LSD ($P \leq 0.05$)	8.4
Hacklins Corner	0-5	45.7 ^{a}
	5-10	32.3 ^{a}
	10-20	26.3
	LSD ($P \leq 0.05$)	15.2

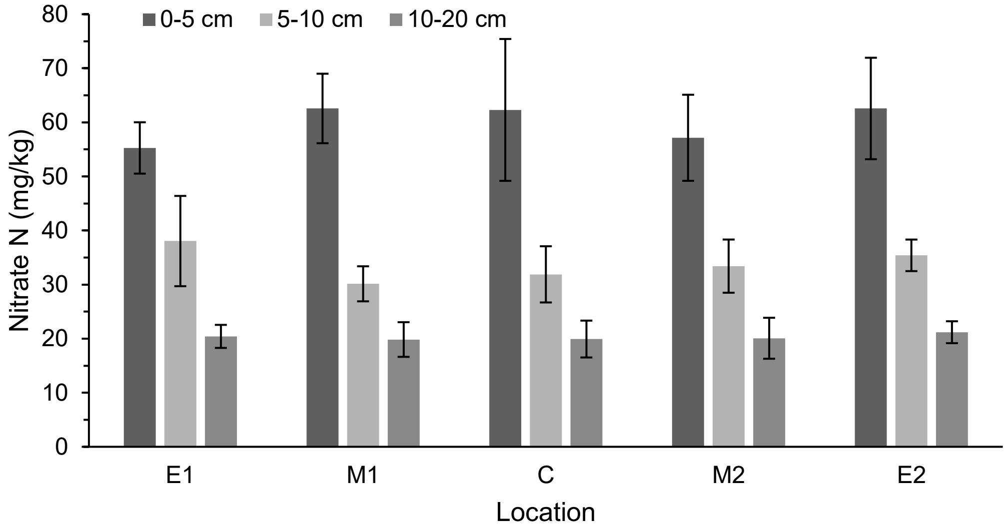

Figure 3. Nitrate distribution across a concentrated line of chaff residue and with depth at the Spalding site. Refer to Figure 1 for location of the sampling points (E1, M1, C, M2, E2).

The Hacklins Corner site was the only site analysed for exchangeable K concentration (mg/kg). Similarly, there was no significant effect of chaff lines on the distribution of exch-K horizontally (Figure 4). Irrespective of location across harvester width, vertical stratification occurred between all three soil layers. The 0-5 cm layer consisted of the highest average concentration of exch-K across all sampling points with 445 mg/kg. The 10-20 cm layer also consisted of a lower exch-K amount when compared to the average of the 0-5 cm and 5-10 cm layers with values of 205 and 357 mg/kg.

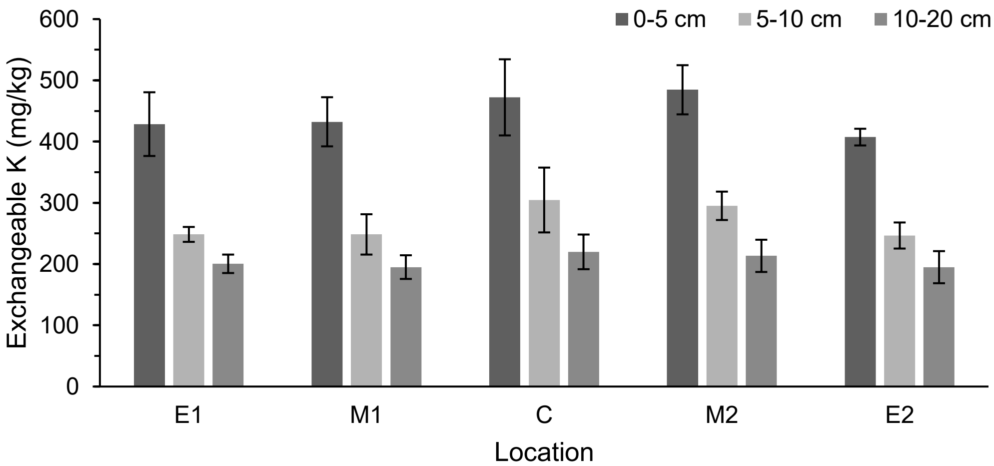

Figure 4. Exchangeable K distribution across a concentrated line of chaff residues and also with depth at the Hacklins Corner Site. E = end, M = middle and C = centre of harvester chaff spread.

Chicken Litter

Significant P stratification ($P \leq 0.05$) occurred in two out of three sites, with available P measures (DGT and Colwell P) both concentrated in the 0-5 cm region (Table 3). The availability of P in the 0-5 cm profile was between 50 to 100% higher than the 5-10 cm interval. Very low P availability was measured in the 10-20 cm region indicating severe stratification of P in these management systems. Phosphorus is an immobile nutrient and doesn't move far away from point source and residue P from fertiliser applications will be restricted to the area of application. Comparison of P distribution with CL application and conventional P application methods indicate that stratification was less severe when CL is applied (Figure 5). This observation needs verification as there was only one control sample taken at each site.

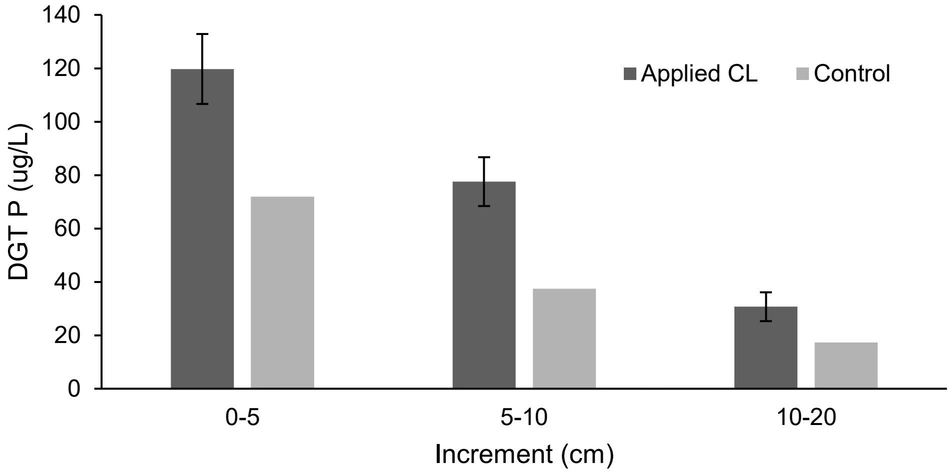

Figure 5. Phosphorus availability (DGT) with depth at the Marrabel site.

Stratification of nitrate occurred at all three sites with the 0-5 cm layer consisting of significantly higher concentrations than the 5-10 cm layer (Table 3). This effect was also evident with total nitrogen (%) where there was a significant stepwise decrease between layers. Comparison of total nitrogen distribution with conventional fertiliser methods indicated that total N concentration was significantly higher with conventional methods at the Marrabel site (Figure 6).

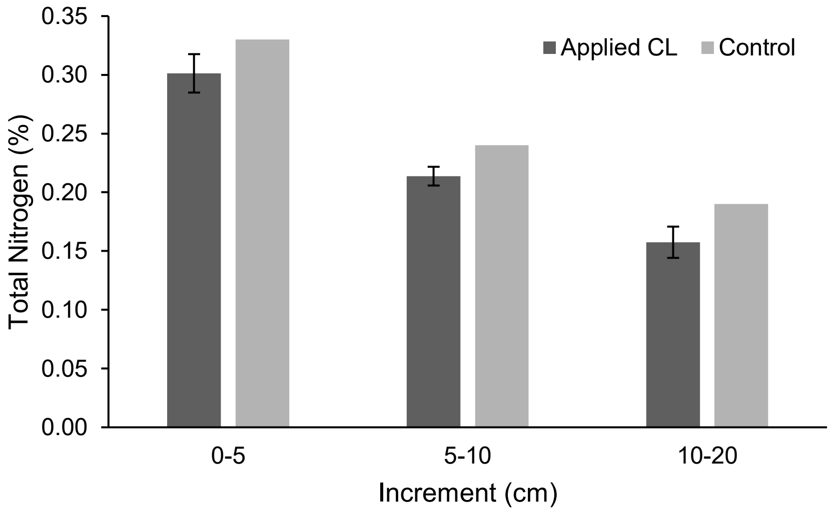

Figure 6. Total nitrogen (%) with depth at the Marrabel site.

Table 3. Average concentrations of nitrate (NO_3 mg/kg), total nitrogen (%), Colwell P (mg/kg), DGT (ug/L), MCP sulphur (mg/kg) and total carbon (%) for all three sites where chicken litter has been applied. Where present, different letters denote significant differences (P≤0.05) between depths at the same site only.

Site	Increment (cm)	NO_3 (mg/kg)	Total N (%)	Colwell P (mg/kg)	DGT P (ug/L)	MCP S (mg/kg)	Total C (%)
Marrabel	**0-5**	79.2 [a]	0.30 [a]	53.6 [a]	119.7 [a]	19.5 [a]	2.93 [a]
	5-10	23.7 [b]	0.21 [b]	39.6 [b]	77.6 [b]	10.6 [a]	1.36 [b]
	10-20	22.4	0.16	23.6	30.7	13.3	1.99
	LSD(P≤0.05)	8.5	0.02	3.5	17.7	2.0	0.23
Hill River	**0-5**	51.7 [a]	0.28 [a]	63.6 [a]	101.9 [a]	19.4	3.18 [a]
	5-10	32.2 [b]	0.23 [b]	45.1 [b]	49.1 [b]	20.0	2.56 [b]
	10-20	24.9	0.12	19.0	9.5	21.6	1.45
	LSD(P≤0.05)	7.7	0.04	6.4	24.6	ns	0.31
Hart	**0-5**	44.7 [a]	0.23 [a]	32.4 [a]	77.8 [a]	10.7 [a]	2.46 [a]
	5-10	38.3 [b]	0.18 [b]	33.2 [a]	66.4 [a]	11.4 [a]	2.01 [c]
	10-20	25.9	0.14	15.1	11.9	6.2	2.11
	LSD(P≤0.05)	4.6	0.01	10.4	51.2	2.9	0.10

Sulphur levels (mg/kg) were significantly higher in the top 10 cm at the Hart site only. At all three sites there was no difference in concentration between the 0-5 cm layer and the 5-10 cm layer (Table 3). Vertical S stratification did not occur at Hill River, indicating that S may not be a nutrient prone to stratification in this soil type/environment.

Carbon (total C%) concentration varied significantly between soil layers at all three sites. A stepwise decrease occurred at both the Marrabel and Hill River site (Table 3). At the Hart site the 0-5 cm layer consisted of the highest concentration of C. Comparison of C distribution with conventional methods at the Hill River site indicated that C concentration was higher with conventional fertiliser applications (Figure 7). This will need further verification to account for other differences between samples (location, soil type, previous crop type etc.).

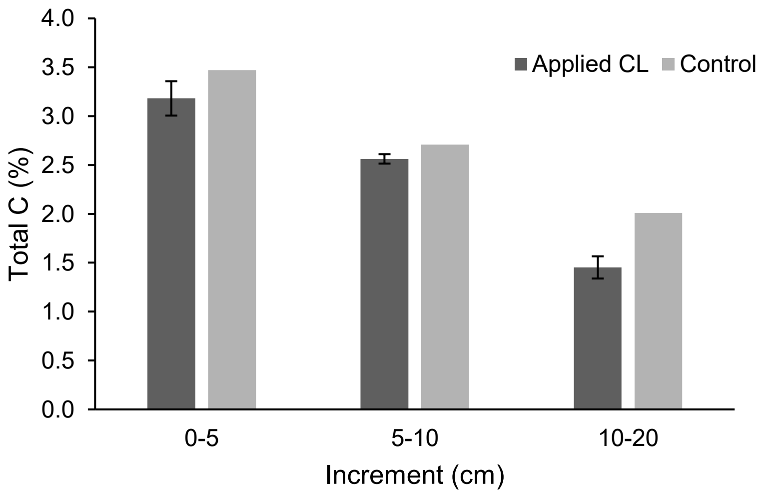

Figure 7. Total carbon (%) with depth at the Hill River site.

Summary / implications

This survey highlights that chaff distribution had no significant impacts on nutrient stratification either horizontally or vertically across the landscape at these three sites. Chicken litter applications appear to compliment traditional chemical fertiliser applications by increasing P availability which supports recent glasshouse and field trial results. Of note is that all nutrients assessed were well above established critical levels. There was a tendency for all nutrients to be concentrated at the surface (0-5 cm) regardless of the known differences in mobility between N, P, K and S.

Grain crops can utilise significant amounts of nutrients located below the surface layer which need to be accounted for in soil sampling protocols if an accurate prediction of nutrient availability is to be achieved. For some nutrients, root uptake efficiency is maximised when the entire root surface has access to nutrients (in an appropriate chemical form) rather than supply only a small proportion of the root system with nutrients.

Deep soil sampling to depth (0 – 60 cm or deeper) prior to sowing by growers/advisers has been a recommendation for N only (and very recently for K and S) for some time, although the actual adoption of this practice varies greatly but is generally thought to be low. Soil testing to depths >10 cm for plant available P is a relatively new concept and has not typically been employed to predict fertiliser responses under commercial conditions. Assessing the accuracy of soil testing for sub-surface nutrients has been dominated by data from WA (K and S) and QLD (K and P).

Hart's regional intern Rochelle Wheaton soil sampling paddocks for the nutrient stratification field survey, 2016.