Just how much are nutrients redistributed unevenly across the paddock when canola and wheat is windrowed?

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Key messages

The practical implications of nutrient redistribution within paddocks by windrowing can be approximated by measuring plant material and investigating nutrient leached after rainfall.

After harvest the difference in the total amount of N, P and K on and off windrows was worth $499/ha and $518/ha in fertiliser equivalents for canola and wheat respectively.

Large amounts of plant-available K were redistributed by windrowing.

The quantity and plant availability of plant material redistributed during harvest needs further investigation as it has major implications for fertiliser decisions and stubble management.

Aims

To gauge the nutrient cost of windrowing by estimating the total amounts of key nutrients redistributed onto stubble windrows when canola and wheat are harvested and analysing their plant-availability after a rainfall event.

The differential between nutrient load on and off windrows can be calculated from reported nutrient concentrations and harvest indexes, but rarely is it directly measured, particularly not the quantity, nutrient concentrations and plant-availability of straw/chaff that comes out the back of the header.

We thought it would be timely to actually measure nutrient redistribution from windrowing because concentrating stubble into strips is affecting production, soil testing and fertiliser decisions for subsequent crops.

Method

In November 2017 at Wyening Mission Farm, Calingiri, prior to harvest we measured:

- Harvestable biomass (consisting of stems/leaves/pods and seed) of Hyola 404RR canola that was
    a) to be direct-headed, and
    b) swathed and windrowed ready for harvest
- Harvestable biomass of Scepter wheat prior to direct-heading
- Seed yields at harvest using the yield monitor on a 40 foot (12.2m) New Holland 9090 header.

After harvest we measured:

- Above ground residues of canola and wheat still standing in the soil
- Straw/chaff deposited onto a 4 foot (1.2m) windrow.

Measurements were made for both direct-headed and swathed canola to ensure results were applicable to both harvesting methods.

All samples were analysed for total nutrient contents by Apal Laboratories. Finely ground dry samples were analysed by DUMAS method for N, and P and K in samples were analysed by microwave digestion and ICP-OES analysis.

Straw/chaff samples of canola were analysed for soluble nutrient contents in an attempt to mimic how a rainfall event may leach nutrients in order to approximate the monetary value in fertiliser equivalents of nutrients redistributed at harvest. Ground samples (20g) were shaken with Milli-Q water (100ml) on an end-over-end shaker for 24 hours, the soluble extract decanted and centrifuged at 4000 rpm for five minutes and then the solution analysed. While previous experiments have used wider plant to water ratios (e.g. 60:1 Noack et al 2012), we used a 5:1 ratio to try to mimic a single rainfall event. Further work is required to further expand and refine this methodology because it is likely the method extracted the salts that were soluble at the time but not the total amount of nutrients that would solubilise in the field as straw/chaff goes through iterations of wetting and drying.

Results

Biomass and nutrient concentrations

The direct-headed and swathed canola had similar harvestable biomass (Table 1) indicating the plant material sampled for direct-headed canola was similar to what had been swathed. Similar results for stems/leaves/pods going into the header and straw/chaff coming out the back of the header confirms accurate sampling of harvestable biomass and minimal loss of non-seed material through the header. Harvest indexes were 0.19 and 0.49 for canola and wheat respectively.

Table 1. Biomass and nutrient concentrations of canola and wheat components.

	Dry matter (t/ha)	N (%)	P (%)	K (%)
Canola				
Soil-attached residue	2.6	0.49	0.02	1.33
Harvestable biomass:				
Stems/leaves/pods – direct-headed	2.9	0.49	0.03	1.48
Stems/leaves/pods – swathed	2.8	0.58	0.04	1.22
Seed	1.3	3.27	0.59	0.72
Straw/chaff out the back of header	3.1	0.59	0.03	0.95
Wheat				
Soil-attached residue	2.5	0.63	0.01	1.03
Harvestable biomass:				
Stems/leaves/pods – direct-headed	2.3	1.27	0.13	0.67
Seed	4.5	1.80	0.24	0.44
Straw/chaff out the back of header	2.4	0.40	0.02	1.72

Nutrient quantities at harvest

Most of the P in plants was removed in seed at harvest with very little remaining on the paddock in plant material (Table 2). About one third of N remained on the paddock after harvest for both canola and wheat, roughly split between soil-attached residue and straw/chaff. Only 11% and 33% of K in canola and wheat was removed in seed leaving 64 kg/ha and 66 kg/ha of K on the paddock. In canola this remaining K was split 55:45 between soil-attached residue and straw/chaff whereas in wheat the split was 40:60.

Table 2. Nutrient quantities and harvest indexes in canola and wheat components.

	N (kg/ha)	P (kg/ha)	K (kg/ha)
Canola			
Soil-attached residue	13	1	35
Harvestable:			
Stems/leaves/pods – direct-headed	14	1	42
Stems/leaves/pods – swathed	16	1	34
Seed	42	8	9
Straw/chaff out the back of header	18	1	29
Nutrient harvest index	0.61	0.85	0.11
Wheat			
Soil-attached residue	16	0	26
Harvestable:			
Stems/leaves/pods – direct-headed	29	3	15
Seed	81	11	20
Straw/chaff out the back of header	9	0	40
Nutrient harvest index	0.65	0.77	0.33

Nutrient redistribution to windrows

A 10-fold increase in the amount of straw/chaff on windrows by harvesting concentrated huge quantities of N and K into strips (Table 3). In canola, compared to evenly spread straw/chaff, windrowing reduced K off windrows by 29 kg/ha and increased it on windrows by 266 kg/ha creating an off:on windrow differential of 295 kg/ha. In wheat the differential was 410 kg/ha with off windrow 40 kg/ha less than evenly spread chaff.

Table 3. Impact of windrowing on nutrient quantities post-harvest (all values include soil-attached residue).

	N (kg/ha)	P (kg/ha)	K (kg/ha)
Canola			
Straw/chaff spread evenly (100% of header width)	31	2	64
Straw/chaff windrowed:			
Off windrow (90% of header width)	13	1	35
On windrow (10% of header width)	194	10	330
Wheat			
Straw/chaff spread evenly (100% of header width)	25	1	66
Straw/chaff windrowed:			
Off windrow (90% of header width)	16	0	26
On windrow (10% of header width)	111	5	436

Solubility of plant nutrients

The extraction method removed 8, 32 and 55% of the total N, P and K from canola straw/chaff. Approximately half the water was absorbed by the straw/chaff in the extraction process simulating a medium rainfall event.

Conclusion

Large quantities of nutrients on windrows

Most of the nutrient concentrations of the plant parts measured here were similar to commonly used values (e.g. Fisher et al. 1998, Pluske and Bowden 2004). The stems/leaves/pods samples here were different to the commonly reported “straw” sample analyses which may explain why K concentration of canola stems/leaves/pods was 50% of reported values for straw and N and P concentrations for wheat were about 2 and 5 times higher (Fisher et al 1998; Gupta 2011). The straw/chaff samples, having been collected out the back of the header, are harder to compare to other analyses, however the K concentration of 1.72% for wheat straw/chaff here was much higher than commonly reported values for straw that range from 0.40 to 1.30%.

K was the nutrient most affected by windrowing in both canola and wheat. In canola, regardless of whether it was swathed or direct-headed, even spreading of straw/chaff across the whole header width left 64 kg/ha of K in plant material on the paddock, 29 kg/ha from the straw/chaff and 35 kg/ha from soil-attached residue. Windrowing reduced this to 35 kg/ha off the windrow (just the soil-attached residue) and increased it to 330 kg/ha on the windrow. In wheat there was 66 kg/ha of K with an even spread of straw/chaff compared to 26 kg/ha and 436 kg/ha off and on the windrow after harvest.

Windrowing also caused large differentials in the amount of N off and on the windrow; 181 kg/ha and 95 kg/ha for N in canola and wheat respectively. P quantities were much lower than N and K across the board yet windrowing still created off:on windrow differentials of 9 kg/ha and 5 kg/ha for canola and wheat.

Expensive redistribution of nutrients

In fertiliser equivalents (fertiliser-K cost of $1/kg), the total amount of K redistributed from between canola windrows was worth $29/ha and an extra $268/ha worth of K was deposited onto windrows. The differential in total K between on and off canola windrows was equivalent to $295/ha of fertiliser-K. The on:off windrow differentials in canola for total N and total P were $181 and $23/ha respectively (fertiliser-N cost of $1/kg and fertiliser-P cost of $2.50/kg).

In wheat the on:off windrow differentials in the total amounts of N, P and K were worth $95/ha, $13/ha and $410/ha in fertiliser equivalents.

Because not all the N, P and K in straw/chaff is available to plants, their immediate value relative to fertilisers can be approximated from their water-solubility. Here we mimicked a single rainfall event to gauge, for instance, how much nutrient is likely to be available to establishing plants after a first flush of rain. The higher water-solubility of K measured here is consistent with other findings that K is lost from plant residues quicker than N and P (Schomberg and Steiner 1999) but 55% solubility is lower than other reported values (e.g. Pluske and Bowden (2004)) because more K becomes bio-available each time plant material is wetted. Similarly, the 32% water-extractability of P here was lower than the 65 – 95% for stems reported by Noack et al (2012) most likely because they extracted P using a 60:1 water to stem ratio plus sonication. N solubility was low and, combined with likely immobilisation when N is released

(Christensen 1985), this suggests there are unlikely to be short term consequences for subsequent crops despite large quantities of N being redistributed by windrowing.

Practical consequences of nutrient redistribution

Compared to evenly distributing straw/chaff, windrowing of canola and just a first flush of rain would be like mining $16/ha of fertiliser-K from between windrows and applying it as an extra $146/ha of fertiliser-K onto windrows. There would be $152/ha more fertiliser-K on the windrow than off it. For N and P there would $14/ha and $8/ha more fertiliser on windrows than off them.

The fate of nutrients on windrows will depend on whether straw/chaff is retained, grazed, baled or burnt (Pluske and Bowden 2004). If windrows are burnt, redistribution and loss of nutrients will differ for individual nutrients and depend on if it rained before burning and where ash ends up. The amount and frequency of pre-burning rain is likely to affect how much nutrient leaches from straw/chaff into nutrient rich strips. Clearly when it comes to the fate of nutrients in stubble, many of the knowledge gaps identified in the past (Pluske and Bowden 2005) still remain.

Redistribution of K through windrowing has major implications for practical fertiliser management and it is often a cause of "waves" in paddocks (Brennan et al 2004). Soils that may otherwise be unresponsive to fertiliser K will be depleted of K across most of the paddock to the point fertiliser K is required, yet windrow strips within the paddock will have luxury levels of K. Subsequent harvesting or spreading of windrows won't even up the paddock if the nutrients have already exited the plant material. When K fertiliser is applied across a paddock the portion applied to K-rich windrows will be wasted. Soil test results and subsequent fertiliser recommendations will vary depending on whether samples were collected on or off new or old windrows before or after summer/autumn rains. Historically, instructions for soil sampling suggest not sampling small unrepresentative areas, presumably like nutrient-rich windrow strips. This is easy when last year's windrow can be seen but becomes increasingly difficult over time if windrowed strips are shifting. If windrows are on the same strips every year, sampling is simpler but the compounding effect of concentrating nutrients on those strip is frightening.

More work is required to measure and understand the nutrient costs of windrowing so they can be weighed up against the benefits of the operation.

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Key words

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