Nutrient status of soils and crops in the high rainfall zone of Victoria and South Australia

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Abstract
Canola and wheat grown in the high rainfall zone (HRZ) of Victoria and South Australia can potentially produce grain yields over 4 and 8 t/ha, respectively. However, the average in the region are less than half these values. Such high yielding crops require substantial application of inputs, the most costly being fertilisers. Decisions about nitrogen fertiliser rates are generally based on the difference between the nutrients required for a targeted yield and the estimated amount of nutrients supplied from the soil. However, limited research has been conducted in the HRZ relating the nutrient response of crops to soil nutrient status, and critical soil test values are either not known or are estimated from other regions and soil types. An improved understanding of this relationship will reduce the risk of either under or over applying fertilisers, hence maximising returns to growers. This paper reports on a survey conducted in the HRZ to assess the status of the major and trace nutrients in soils and crops. Results from soil and plant analyses were compared to established critical values to determine if there were any common deficiencies. Survey data was used to identify sites to develop nutrient response curves to help predict the economic and production risks of under or over supplying fertilisers in the HRZ.

Key words
Crop nutrient requirement, field survey, trace nutrients

Introduction
The high rainfall zone (HRZ) of southeastern Australia (500 – 900mm rainfall/year) provides the climatic environment and soil resources in which canola can yield 3-5 t/ha and wheat can yield 9–11 t/ha with current varieties (Riffkin and Sylvester-Bradley 2008). Additionally, newly introduced winter-type canola cultivars have achieved yields over 7 t/ha under experimental irrigated field conditions (Acuña *et al*. 2011; Riffkin et al. 2012; Christy *et al*. 2013). Despite these high potentials, the current average yield is only 1-2 t/ha for canola and 2-3 t/ha for wheat, due to abiotic (e.g fertility, waterlogging, subsoil acidity) and biotic (e.g. fungal diseases, insect pests) stresses (Riffkin and Sylvester-Bradley 2008; Riffkin *et al*. 2012). Attaining yields closer to these high potential yields requires additional inputs, and the biggest single cost is fertiliser (Rural Solutions SA 2013). Greater understanding is being sought by growers when targeting high yields to reliably predict how much fertiliser to apply. Growers need to balance the risk of under applying fertiliser which limits yield against over applying fertilisers and wasting inputs. Nitrogen fertiliser requirements are generally based on the difference between the nutrients required for a targeted yield and the estimated amount of nutrients supplied from the soil. Balancing N with other essential nutrients such as P, K, S, Cu and Zn is important to attain high grain yields.

Critical soil test values for P, K and S can be sourced from The Better Fertiliser Decisions for Crops database (BFDC) for crops grown in various soils and regions. However, the database highlights that datasets are limited to "traditional" cropping regions and predominantly focused on N and P nutrition in wheat (Conyers *et al*. 2013). There are few datasets for wheat and almost no datasets for canola responses to nutrients in the HRZ of southeastern Australia. As a consequence, growers and advisers in the HRZ rely on critical soil test values and nutrient response information generated in lower rainfall environments and on different soil types. These values may or may not be valid in the HRZ.

A field survey of soil, tissue and grain conducted in southeast South Australia and southwest Victoria aims to establishing baseline knowledge about the current nutrient status of soils, and canola and wheat crops in the region. The first year of field survey data was also used to identify field sites for nutrient omission experiments that are designed to test the validity of critical soil test values and response curves for high yielding crops in the HRZ. A second year of sampling will be conducted in 2015. This paper presents the findings for the first year.

Methods

Soil, tissue and grain samples were taken from commercial crops in southeast South Australia and southwest Victoria from April to August 2014 with sites ranging from Frances to Inverleigh. All samples were analysed for nutrients at Nutrient Advantage Laboratories, Werribee, using commercially available analysis methods. Soils were sampled in South Australia at 12 sites prior to fertiliser application and were subjected to a comprehensive soil nutrient analysis in increments: 0 to 10 cm, 10 to 30 cm, 30 to 60 cm and 60 to 100 cm. Tissue samples (39) were taken from three wheat cultivars (cv. Revenue, Bolac and Derrimut) at Growth Stage (GS) 31 and triazine-tolerance canola at Growth Stage 3.3 (bud first visible) by sampling youngest emerged leaves. Leaves were collected from at least 100 wheat or canola plants in July and August at each site. Grain samples of the same wheat cultivars and canola type were taken from two sources. The first source was the crops sampled for soil and tissue analysis in southeast South Australia. The second source was grain from 49 farms in the target region that delivered to GrainCorp® receival sites at Geelong and Naracoorte. All tissue and grain samples were analysed for nutrient concentration of B, Ca, Cu, Fe, Mg, Mn, P, K, Na, S, Z, N, Mo ('T3' test).

Results

Soil analysis from this first year of field sampling showed that some paddocks in southeast South Australia had low soil nutrient concentrations for S, Cu, Mn and/or Zn, and this is consistent with earlier surveys (Donald and Preston 1975) (Table 1). Most other nutrients in South Australia were deemed adequate according to critical soil test values (Peverill *et al*. 1999; GRDC 2013).

Table 1: Nutrient analysis of soil in southeast South Australia immediately prior to the 2014 cropping season for 0-10 cm (n=12) and 10-30 cm (n=12).

		Critical value in	0-10 cm				10-30cm			
Soil analysis	Units	0-10 cm layer	Min.	Average	Max.	StDev	Min.	Average	Max.	StDev
pH (1:5 Water)		-	5.5	7.5	8.6	1.1	7.2	8.2	8.7	0.6
pH (1:5 CaCl2)		-	4.9	7.0	7.9	1.1	6.1	7.4	8.1	0.7
Mineral N (NO3 + NH4)	mg/kg	-	2.7	22.7	85.0	23.9	3.6	13.5	30.2	9.1
Phosphorus (Colwell)	mg/kg	25	23.0	49.9	73.0	14.9	5.3	10.5	18.0	4.1
Phosphorus Buffer Index (PBI-Col)		-	57.0	118.1	180.0	44.4				
Sulfate Sulfur (KCl40)	mg/kg	5	4.4	23.6	62.0	21.2	3.3	13.9	39.0	10.5
Calcium (Amm-acet.)	Meq/100g	1	4.0	28.0	55.0	18.6	6.5	25.8	41.0	13.7
Potassium (Amm-acet.)	Meq/100g	0.25	0.3	1.7	4.9	1.5	0.4	1.1	3.2	0.9
Magnesium (Amm-acet.)	Meq/100g	0.2	1.0	5.1	13.0	4.3	1.8	7.6	15.0	3.4
Sodium (Amm-acet.)	Meq/100g	-	0.3	0.8	3.9	1.1	0.2	1.6	3.1	1.2
Cation Exch. Cap.	Meq/100g	-	6.2	38.5	61.6	21.2	17.5	36.0	58.6	14.3
Calcium/Magnesium Ratio		-	2.5	6.4	13.0	3.7	0.8	4.8	18.0	5.2
Copper (DTPA)	mg/kg	0.4	0.3	0.8	1.3	0.3				
Iron (DTPA)	mg/kg	-	7.2	144.3	530.0	187.3				
Manganese (DTPA)	mg/kg	5	0.9	3.9	8.8	2.7				
Zinc (DTPA)	mg/kg	0.4	1.1	3.5	12.0	3.3				
Boron (Hot CaCl2)	mg/kg	0.5	0.9	2.0	4.3	1.1				

The nutrient concentrations of canola at 'first bud visible' (Stage 3.3) were generally above the reported critical values, although some crops tested had micronutrients applied either with fertiliser or as foliar supplements. Nutrient concentrations in wheat at GS31 were generally above critical values for major nutrients although several had low concentrations of Mg, Cu and Zn (Table 2).

Grain sourced from GrainCorp® provided a sample of grains from a cross-section of grain enterprises in the region including growers operating low and high input systems. Grain nutrient concentrations were considered adequate for most nutrients in most paddocks although copper concentrations in canola (1.6 – 3.2

mg/kg) were at the lower end of the range whilst P and K concentrations in wheat were often below critical values proposed in Reuter *et al*. (1997) (Table 3).

Table 2: Nutrient analysis of wheat tissue at GS31 (n = 23) and canola tissue at 'first bud visible'(n = 16) sampled during the 2014 cropping season. Critical values are minimum value for adequate nutrition as sourced from Reuter *et al.* (1997).

		N	P	K	S	Ca	Mg	Na	Mn	Fe	B	Cu	Zn	Mo
	unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Wheat tissue at GS31	Critical value	35000	3000	24000	1500	2100	1500	-	15.0	-	5.0	3.0	20.0	0.1
	Min.	37000	2300	25000	2600	1300	800	100	37.0	57.0	2.3	1.1	13.0	0.1
	Average	52391	3848	38435	3935	2970	1374	374	93.9	99.0	4.0	5.0	27.6	0.6
	Max.	67000	5600	48000	5200	5000	2200	700	230.0	180.0	7.9	9.4	71.0	3.5
	StDev	8500	1016	6207	778	1091	376	203	44.9	29.7	1.3	2.4	14.9	0.8
Canola tissue at 'first bud visible'	Critical value	53000	3200	28000	4700	1400	2100	-	-	-	22.0	4.0	22.0	-
	Min.	62000	6400	29000	7000	5700	2200	600	25.0	78.0	27.0	3.0	27.0	0.2
	Average	72625	8444	33250	8269	9456	3294	2444	50.3	154.5	32.3	5.4	52.9	0.4
	Max.	83000	12000	38000	9900	12000	4900	4400	93.0	670.0	39.0	7.4	82.0	1.3
	StDev	6622	1275	2769	747	2061	641	1121	19.9	145.7	3.7	1.5	13.2	0.3

Table 3: Nutrient analysis of wheat (n = 35) and canola (n = 28) grain sampled at the end of the 2014 cropping season. Critical values are minimum value for adequate nutrition as sourced from Reuter *et al.* (1997) and Norton (2014).

		N	P	K	S	Ca	Mg	Mn	Fe	B	Cu	Zn	Mo
	unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Wheat grain	Critical value	-	2700	5000	1200	-	-	20.0	-	2.0	2.5	15.0	-
	Min.	17000	1300	2900	1200	200	700	5.9	17.0	1.3	1.9	12.0	0.1
	Average	22171	2589	3883	1531	340	1029	38.6	34.1	2.3	3.4	22.5	0.2
	Max.	26000	3900	5900	1800	500	1300	58.0	50.0	3.2	4.9	37.0	1.0
	StDev	2332	589	572	155	69	127	12.3	6.9	0.4	0.8	6.7	0.2
Canola grain	Critical value	19000	3500	-	3600	-	-	10.0	-	1.0	3.0	15.0	
	Min.	34000	2900	5300	3500	1800	2300	22.0	35.0	11.0	1.6	21.0	0.1
	Average	37000	5400	6489	4182	3246	3007	36.3	99.1	15.4	2.4	34.8	0.3
	Max.	41000	8900	7700	4800	4400	3600	45.0	510.0	19.0	3.2	56.0	0.5
	StDev	1785	1423	815	371	614	318	5.5	100.7	2.2	0.4	6.5	0.1

Discussion

This snapshot of crop nutrient status in the HRZ of southeast Australia suggests that overall plant nutrition is adequate for current grain yields. However, there is a broad range of values for some nutrients in soil and tissue, so there are opportunities to improve nutrition for those crops. There was generally no relationship between soil nutrient status and plant nutrient status at the South Australian sites except possibly Cu in tissue. Similarly, relationships between soil and grain nutrition were also lacking in larger datasets sourced from National Variety Trial (NVT) sites (Norton 2012, Norton 2014). This is important given nutrients P, K and S and some trace elements are often applied at sowing based on critical soil test values rather than on how much nutrient will be removed by a crop.

Canola tissue tests consistently showed higher nitrogen and lower calcium concentrations in the youngest mature leaves than required for adequate nutrition. This could be a result of cold conditions slowing crop growth and nutrient movement through the plant, rather than a low soil supply. This highlights the need to consider weather conditions at the time of sampling when interpreting tissue analysis as part of an in-season fertiliser program.

Grain nutrient concentrations from this random sampling of canola crops were similar to grain collected from NVT sites in the same regions (Norton 2014). However, grain nutrient concentrations of P, K, S, Ca and Mg were lower in wheat grain collected in 2014 than in wheat grain sourced from NVT sites in southeast South Australia (Norton 2012). This difference between datasets may be due to the wheat grain largely being sourced from southwest Victoria rather than southeast South Australia. Whilst these grain nutrient concentrations can be a useful guide, the interpretive values are not clear for Australian conditions.

Future nutrient management research in the HRZ aims to determine the fertiliser strategies needed to meet nutrient demand when targeting higher grain yields and test the validity of critical nutrient values for high yielding crops using nutrient omission experiments in the field. Currently, the cost of applying sufficient fertiliser to achieve an 8 t/ha of wheat crop in southwest Victoria is estimated to be $216 (Andrew Speirs, pers. comm.) on a soil with non-limiting K and S and no provision for nutrient replacement. Even though a fertiliser program to meet those demands would cost roughly 1 t/ha of wheat, at this stage most growers and agronomists consider the economic risk of incurring such fertiliser costs are too high. The opportunity cost of not using these higher rates of fertiliser needs to be better understood by growers and agronomist so that the yield potential of this region can be achieved.

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