Recurrence of yield and protein variation in the northern grains region

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Abstract

Grain yield and protein maps of sorghum and wheat were collected over consecutive seasons at Jimbour (southern QLD) and at Gurley (northern NSW) to identify spatial and temporal changes in nitrogen (N) removal and N supply. The Jimbour site was cropped with sorghum for 3 years (1999-2001), and the Gurley site with wheat (1999) then fallowed into sorghum (2001). Grain yield variation was moderate to high; coefficients of variation (CV) ranged from 12 to 30%. Protein variation was low for each site and season with CVs below 10%. At Jimbour, high applications of N fertiliser minimised temporal variation in grain protein. At Gurley, matching of N fertiliser with yield potential (based on soil depth) also resulted in a low temporal variation in protein. The low protein variation, both within seasons and between seasons, then contributed little to the temporal variations in N removal. Both sites had areas of stable variation but low supplies of N; these were related to areas where moisture had pooled or where soil depth, and hence available soil moisture, limited yields. Unstable variation was associated with isolated trees, contour, or edge effects. Under these conditions, protein data may need to only be collected every 2-3 years.

Key Words

Precision agriculture, temporal stability, nitrogen supplies, site-specific management

Introduction

In the northern grains region, retrospective analyses of the combined grain yield and grain quality outcomes can provide insights into the success or otherwise of the nitrogen (N) management strategy adopted for a particular crop in a given season (1). For example, grain yield of wheat with a protein concentration of <12.5% is likely to have been limited by lack of N in the soil. These principles can be applied on a spatial basis to determine if N was limiting yields of wheat, sorghum or barley crops (2).

Prudent N management requires an understanding of the removal of N by crops. It follows that an understanding of the temporal stability of N supply may be identified with management practices that replenish soil reserves of N, or those that lead to a decline in N supply. Within-field assessment of this stability of N supply could identify those areas where a uniform application of N was inefficient due to variation in soil type or soil depth. In this study, we documented changes in grain yield, protein, and N supply for more than one season to identify spatial and temporal changes in N.

Methods

Site locations and crops

Yield and protein measurements were collected from sequences of grain crops at two locations. A site located at Jimbour, southern Queensland (26.976?S, 151.134?E; herein referred to as the Kielli site), was sown with three successive sorghum crops (cv. Bonus) in December 1998, October 1999, and December 2000. The field was located on a deep black Vertosol (3) with a soil depth typically >1.8 m, and plains topography. Each crop received 190, 8, 1 and 0.5 kg/ha equivalent of N, phosphorus, sulfur and zinc respectively. These were applied uniformly in the field as urea prior to planting or as zinc-coated ammonium phosphate with the seed. The field size was 42 ha.

A site located east of Gurley, northern New South Wales (29.827?S, 150.041?E; herein referred to as the BT site), was sown with durum wheat (cv. Wollaroi) in June 1999, then long-fallowed before sowing with sorghum (cv. Buster) in September 2000. This field was located on grey/black Vertosols of variable depth (3). The depth of soil at this site ranged from 30 to 150 cm based on a push-probe, and the topography was undulating. The size of the field was 45 ha. Crops received variable-rate fertilizer prior to sowing based on soil depth; the wheat crop received between 25 and 75 kg N/ha equivalent, and the sorghum crop received between 30 and 80 kg N/ha equivalent supplied as urea.

Data collection and processing

Grain yield was monitored during harvest at both sites with a yield sensor mounted on the harvester. Differentially corrected global positioning system (DGPS) receivers provided positions accurate to <1 m. Yield data was filtered to remove obvious discrepancies arising from the harvest operation. Values were removed if yield was more than 3 standard deviations (SD) from the mean, if distance travelled per second was <25 cm, if moisture was <6%, or if the position dilution of precision was >5. This resulted in between 0.3 and 3% of the yield data being eliminated from further analysis.

Grain samples were collected during harvest with a side-mounted sampler capable of collecting 70-100 g samples every 30-50 m. The position of each sample was logged using the DGPS. Samples were analysed for grain moisture and protein after harvest with an NIR (near infra-red) spectrophotometer. A subset of 5% of the samples was ground and combustion-analysed to calibrate the NIR with actual grain protein. Protein results were calculated at 13.5 and 12% moisture for sorghum and wheat, respectively. Data was interpolated using VESPER (4) on a 10 m grid to match the cutter-bar width. Further analysis was conducted on these interpolated data sets.

Data analysis and interpretation

Grain yield (t/ha) and grain protein (%) data were combined to determine N removal (kg N/ha) in the grain using the formula: $\text{N removal} = \text{Grain yield} \cdot \text{Grain protein} \cdot a$

where *a* is a factor based on the amount of N present in grain protein (1.6 for sorghum, 1.75 for wheat). Apparent N supply (kg N/ha) was then determined for each crop in both fields using the formula:

$$\text{Apparent N supply} = \text{N removal} \cdot \text{N transfer efficiency}$$

where N transfer efficiency indicates the proportion of soil mineral N converted into grain protein. Results inferred from numerous multi-rate N experiments in the northern grains region suggest that this proportion decreases linearly as the grain protein concentration (%) increases:

$$\text{N transfer efficiency} = a - b \cdot \text{Grain protein}$$

where for sorghum, *a* = 143 and *b* = 9.5, while for wheat, *a* = 135 and *b* = 6.7 (W. Strong, unpublished data). Nitrogen removal and N supply were determined for each site and crop. Temporal classification was conducted using a methodology outlined by Aspinal (2000) and based on Larscheid *et al.* (1997) (5, 6). The methodology uses a 'normalised' measure, relative to the mean, of each parameter (i.e. yield, protein, N removal and N supply) to calculate the temporal coefficient of variation (CV). Using an arbitrary CV threshold of 20% (5), classification rules were applied to each parameter to indicate areas that were 'stable-high' (CV <20% and temporal normalised mean >100%), 'stable-low' (CV <20% and temporal normalised mean <100%), or 'unstable' (i.e. CV >20%).

Results and Discussion

Yield and protein observations

Sorghum yields at Kielli ranged from a low in 1999 of 4.49 t/ha to a high the following year of 7.93 t/ha (Table 1). Spatial yield variation was more apparent for 1999, as indicated by the high CV, than for either of the following crops. A preceding barley crop sown at the Kielli site in 1998 would have reduced the initial soil moisture reserves prior to the 1999 sorghum crop, and subsequent rain during growth was insufficient to optimise yields. The negative correlation between CV and grain yield ($r = -0.96$) indicated that higher yields were associated with more uniformity.

Grain yield at BT, which tended to be much less than that at Kielli, ranged from 0.16 to 6.55 t/ha for wheat (1999), and from 0.37 to 6.54 t/ha for sorghum (2001) (Table 1). Each crop had a CV >20%, likely to have resulted from the within-field variation in soil depth.

Variation in within-field protein concentration of grain crops ranged from as little as 1.9% for the wheat field (BT, 1999) to over 4% for two sorghum crops (Kielli, 1999; BT, 2001) (Table 2). Within-field variation in grain protein concentration at Kielli and BT was less than half that for the grain yield data, with CVs ranging from 3 to 10%.

Table 1. Summary statistics for the grain yield data derived from the Kielli and BT fields.

Field	Year	Mean	Median	99.5%-ile	0.5%-ile	SD	CV
				t/ha			%
Kielli	1999	4.49	4.71	7.14	0.31	1.34	29.8
	2000	7.93	8.04	9.69	3.83	0.93	11.7
	2001	6.18	6.37	7.83	0.44	1.02	16.4
BT	1999	4.45	4.56	6.55	0.16	1.05	23.5
	2001	4.04	4.25	6.54	0.37	1.19	29.5

Grain yields of sorghum associated with protein concentrations of less than 9.5% would probably have benefited from additional N fertilizer (1). Consequently, apparent N supply was likely to have been limiting to yield in some areas of the Kielli 2000 crop (mean of 8.14%) and the BT 2001 crop (mean of 7.99%). For wheat, application of N fertilizer to optimise the chances that grain protein would be >12.5%, thus ensuring higher premiums, also maximised grain yield.

Table 2. Summary statistics for the grain protein data derived from the Kielli and BT fields.

Field	Year	Mean	Median	99.5%-ile	0.5%-ile	SD	CV
				%			%
Kielli	1999	9.63	9.59	11.54	7.31	0.61	6.4

	2000	8.14	8.23	9.98	5.98	0.81	10.0
	2001	9.64	9.60	11.14	8.26	0.51	5.3
BT	1999	12.59	12.48	13.87	11.94	0.40	3.2
	2001	7.99	8.03	9.89	5.36	0.75	9.4

Temporal stability and classification

At Kielli, the temporal CV for grain yield was mostly <30%, with the more variable areas found at the northern and southern edges (Figure 1a). However, temporal CV for protein concentration was <10% highlighting a consistent pattern within the field for the 3 years (Figure 1b). Temporal CV for both N removal and apparent N supply were similar to that of grain yield (Figure 1c,d). This reflected the lower CV in grain protein for all years, and a reduced leverage in the calculation of these parameters.

Yield at Kielli was found to be largely stable, with much of this producing high yields (Figure 2a). The entire field was classified as having a stable protein output (Figure 2b), presumably in response to the high applications of N. Classification of N removal and N supply at Kielli indicated that the southern part of the field had consistently lower N supplies (Figure 2c,d). This corresponded to an area where pooling occurs after localized flooding, which may have led to losses of N.

At BT, temporal CV for grain yield exceeded 30% in the south (Figure 3a), which matched where isolated trees were present. Grain protein tended to be highly stable across the 2 years with the temporal CV <10% (Figure 3b). Uniformity in grain protein concentration, due to the N management strategy in which N fertilizer was applied according to soil depth, led to the grain yield providing a surrogate indicator of N removal and N supply (Figure 3c,d). Yield tended to be unstable over the 2 years in areas where trees were retained (Figure 4a). Stable but low yielding areas matched areas of shallow soil depth. Protein variation was stable over time throughout the field (Figure 4b). Nitrogen removal and N supply was classified in a similar fashion to that of grain yield: greater amounts of N were removed and were available from the deeper soil profiles (Figure 4c,d).

Nevertheless, the identification of areas where protein concentration for sorghum was below the critical level of 9.5% suggests that although the spatial management of N was appropriate, absolute rates could be better matched to available water from season to season. Collection of data from more than the two seasons would more clearly indicate temporal stability.

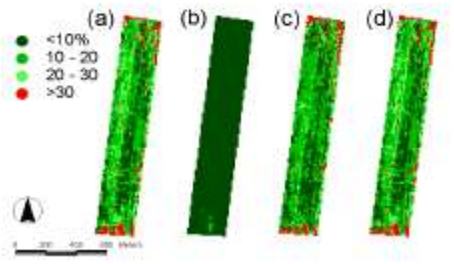

Figure 1. Temporal coefficient of variation observed at Kielli for (a) yield, (b) protein, (c) N

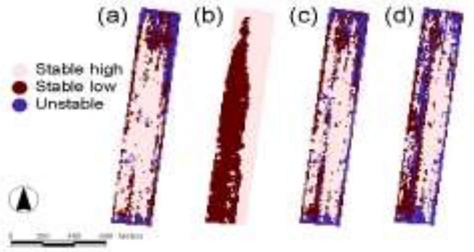

Figure 2. Stability classes observed at Kielli for (a) yield, (b) protein, (c) N removal, and (d) N

removal, and (d) N supply.

supply.

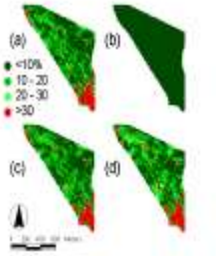

Figure 3. Temporal coefficient of variation observed at BT for (a) yield, (b) protein, (c) N removal, and (d) N supply.

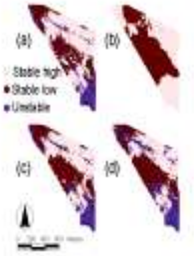

Figure 4. Stability classes observed at BT for (a) yield, (b) protein, (c) N removal, and (d) N supply.

Conclusions

A number of practical implications are suggested as a result of this study. Firstly, strategies that reduce temporal variation in grain protein, such as applying high rates of N or matching N with yield potential (i.e. available water), will ensure that grain yield remains a reasonable surrogate estimate of N removal and apparent N supply. Further analyses of absolute values of grain protein, although not conducted in this study, could calculate actual amounts of N removed or remaining. Secondly, in these circumstances, determining spatial variation in grain protein need only take place every 2-3 years. Thirdly, spatial patterns of apparent N supply are consistent from year to year presumably due to stable landscape and environmental features that influence apparent N supply. These methodologies need testing in more variable landscapes, and over a longer timeframe.

Acknowledgements

The authors are grateful to Jamie Grant and Mike Smith for allowing access to their fields. This research was funded by the GRDC and the Queensland Department of Primary Industries.

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