Working with farmers to benchmark high-yielding durum wheat on the Liverpool Plains

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ABSTRACT

Growers in the Liverpool Plains (NNSW) were keen to identify the factors limiting durum wheat yields and the level at which they should be setting target yields. WHEATMAN-generated values for critical plant and soil parameters for durum production were used as benchmarks. Eight commercial durum crops were monitored in 1999.

Low plant population (42-91 plants/m^2) resulting from poor seed quality (60-95%), combined with insufficient nitrate supply (3-27 kg N/ha at harvest at 4 of 5 sites) appeared to be major factors limiting durum yields in the monitored crops (range 4.3-5.3 t/ha). Disease management was also likely to be a contributing factor as crown rot levels in the wheat paddocks were <5% following sorghum and 15-30% following wheat.

KEY WORDS

Benchmarking, water, nitrate, population, disease.

INTRODUCTION

The Liverpool Plains of north-eastern NSW is one of the most fertile and potentially productive agricultural regions in Australia. Durum wheat is a valuable crop, with grain quality premiums generally higher than those paid for bread wheat. During the last decade, Liverpool Plains growers have increased yields of summer crops, particularly sorghum, but have been unable to reliably improve yields of bread and durum wheats. Dryland yields currently average about 3 t/ha, but some paddock yields have reached 7.5 t/ha. After discussions with grower groups it was agreed that research leading to an understanding of the factors underpinning production of high-yielding, high-quality durum would be worthwhile.

We held a series of meetings with growers, local agribusiness agronomists and NSW Agriculture researchers prior to the 1999 winter cropping season to discuss the constraints to producing 7 t/ha, 13% protein durum crops on the Liverpool Plains. Assuming optimal management, it was proposed that such yield and protein levels would be the exception rather than the rule because of (i) an overall lack of water, (ii) water stress at critical development stages, and (iii) rising temperatures at flowering that shorten the grain filling stage (D. Woodruff, pers. comm). Growers accepted these environmental limitations to yield, but were still interested to know where to set target yields for financial and nitrogen (N) budgeting purposes and to identify the factors under their control that were limiting yields. It was agreed that WHEATMAN-generated values for critical plant and soil parameters for wheat production would be used as benchmarks for different levels of yield (7).

Benchmarking and paddock monitoring have been effective in identifying factors limiting production in other grain industries, e.g. rice (4). By closely monitoring commercial paddocks in the Liverpool Plains, we aim to identify limitations to durum wheat production and validate the benchmarks generated from WHEATMAN. In addition, the data will be used to initialise simulation modelling to determine the likely risks and returns associated with setting target yields at different levels.

MATERIALS AND METHODS

WHEATMAN-generated benchmark values

WHEATMAN (6) is a decision support, paddock recording and analysis program for the Northern Winter cereal Regions of Australia. The WHEATMAN-generated benchmarks for critical soil and plant parameters for durum grain yields of 4-7 t/ha are presented in Table 1. The concept is that to achieve the yields in column 1, the corresponding values for row width, seeding rate etc. must be met or exceeded. If not, then the yield potential is set by the limiting parameter. For example, if all of the benchmarks for a 6 t/ha yield are met by a hypothetical durum crop except for head count of 300/m^2, then the yield will be restricted to 4 t/ha. In that crop, head count will represent Von Liebig's limiting factor.

Table 1. Benchmarks for key sowing and plant factors at durum yield levels of 4-7 t/ha, on the Liverpool Plains, NSW.

Yield (t/ha)	Max. row width	Seeding rate (kg/ha)	Plants (no/m^2)	Water use to Flower (mm)	Water use post Flower (mm)	Shoot DM at Flower (t/ha)	Shoot N At Flower (kg/ha)	PAI^A	Heads (No./m^2)	Grain (No/m^2)
4.0	35	45	100	115	144	5.6	103	4.0	300	10525
5.0	35	50	130	140	163	7.0	130	4.5	375	13160
6.0	25	60	155	170	180	8.4	157	4.8	450	15790
7.0	21	70	180	200	185	9.9	183	4.9	525	18420

^{A}Plant area index, equal to LAI+0.5

Sites, treatments and sowing

Eight durum wheat crops, grown on five commercial farms on the Liverpool Plains, NSW, were monitored during the 1999 winter season. Site (farm paddock) details are summarised in Table 2. Sites were chosen to represent the geographic spread of the Liverpool Plains as well as the major soil types. Two of the sites (Mullaley and Spring Ridge) had grown durum in the previous year, whilst the other three sites were long fallowed out of sorghum. At Spring Ridge, two sowing date and two sowing rate treatments were imposed (Table 2). All crops were sown by the growers using commercial planters and following their own sowing rules.

Table 2. Site and sowing details for the five sites in 1999 and NSW Agriculture recommendations.

Parameter	NSW Agr.	Site				
	sow guide	Mullaley	Big Jacks Creek	Tambar Springs	Spring Ridge	Breeza
Soil type		Grey vertosol	Grey vertosol	Black vertosol	Grey vertosol	Black vertosol
Fertiliser N (kg/ha)	Not specific	150	200	85	100	120
Date sowing	Late May-	29/6	24/6	30/6	25/6, 20/7	19/6
Rate seeding (kg/ha)	June	40	50	40	50 and 70	50
Row width (cm)	35-55	23	15	23	23	15
Variety	Not specific	Ka	Wo	Ka	Ya	Ka
Disease	Ka, Ya, Wo	No	Yes	Yes	No	Yes

management	1-year break

Ka – Kamilaroi; Ya – Yallaroi; Wo – Wollaroi

Sampling

The eight crops at the five sites were sampled for soil water and N at sowing and crop physical maturity, plant establishment, shoot dry matter (DM) at flowering and harvest, leaf area index at flowering (LAI), crown rot assessment and grain harvest. At four of the sites, monitored crop (experimental) areas were 60 x 100 m. At the Spring Ridge site, plots were 20 x 200 m. Seven to ten samples were taken from each of the 8 monitored crop areas to determine within crop variation. The sampling points were located in two strips running the full length of the plots on either side of the centre 9.3 m, which was reserved for grain sampling.

For soil water and N, 7 cores/crop were taken to a depth of 1.2 m, sectioned into 0-10, 10-30, 30-60, 60-90, and 90-120 cm layers and processed as described in Herridge et al. (3). Plants were counted in 10 x 2 m row lengths. Seed quality was assessed on 5 x 100-seed samples, with % germination evaluated at 4 and 8 days.

Shoot DM and LAI were determined for 7-10 x 2 m row lengths. The N concentration (%N) of shoots was subsequently assessed for each sample using Kjeldahl analysis. Crown rot (visual and laboratory) was assessed on 50 randomly-selected plants at flowering. Grain yield was determined on 100 x 9.3 m header-harvested areas, with the grain weighed on an electronic weigh bridge. Proteins were determined for each sample using NIR.

RESULTS

Soil water and nitrate at sowing and grain harvest

At sowing, all sites had good levels of soil water, with PAW in the range 166-246 mm. Total in-crop rainfall ranged from 200-325 mm with 100-200 mm in October, essentially replenishing soil water. By grain harvest, only the Mullaley site was dry (42 mm); Big Jacks Creek, on the other hand, still had 200 mm compared to 246 mm at sowing.

At sowing, soil nitrate levels ranged about three-fold, from 113 kg N/ha (Breeza) to 325 kg N/ha (Spring Ridge, 50% below 0.6 m). By grain harvest, nitrate levels at 4 of the 5 sites were low (3-27 kg N/ha). Levels at Spring Ridge, on the other hand were 150-180 kg N/ha. Almost 95% of this residual nitrogen was below 0.6m, suggesting possible restrictions to plant-root growth.

Seeding rate, seed germinability, plant populations and head numbers

Plant populations of the monitored crops were in the range 42–91 plants/m^2, compared to the benchmarks of 102 and 128 plants/m^2 for 4 and 5 t/ha yields. The populations were low despite super-optimal seeding rates of 50-70 kg/ha (benchmark values were 45 kg/ha for a 4 t/ha yield and 50 kg/ha for a 5 t/ha yield). Germinability of the sown seed proved to be variable, ranging from 60 to 95%, and essentially determined plant numbers. The highest head numbers (>400/m^2) were associated with highest plant populations (>90/m^2). Head numbers around 300/m^2 were associated with plant populations of 45-60/m^2.

Disease assessment

The two sites with high levels of crown rot (>15% plants infected) were both sown to durum in the previous year (Mullaley and Spring Ridge). The disease was effectively controlled by a break crop, with <5% incidence of crown rot at the three sites previously sown to sorghum.

WHEATMAN parameters for 5t/ha wheat crop

Ranges of values for the measured plant and soil parameters for the eight durum crops, together with WHEATMAN-generated benchmark values for a 5t/ha crop are presented in Table3. Matching our results against the benchmarks was in some cases difficult, although overall the monitored results matched the benchmark values fairly well. One crop was affected by Fusarium head blight at flowering which decreased the potential yield suggested by the high DM (10 t/ha) at flowering. It is also possible that the benchmarks for plant and grain numbers may be high.

Table 3. WHEATMAN-generated benchmarks with ranges of values for the measured key plant and soil parameters for the eight monitored durum crops.

Plant and soil parameters	WHEATMAN benchmarks	Range for 8 crops - 1999
Yield	5	4.3 – 5.3
Sowing soil water (mm)	*	166 - 286
Sowing soil nitrate (kg/ha)	*	113 – 325
Seed quality (% germination)	*	60 – 95
Seeding rate (kg/ha)	50	40 – 70
Plant numbers (/m^2)	130	42 – 91
Grain protein (%)	*	12.4 – 14.3
Shoot DM (t/ha)	7.0	6.5 – 10.0
Shoot N (kg/ha)	130	130 – 220
LAI	4.0	2.5 – 4.0
Heads (no./m^2)	375	280 – 430
Grain (no./m^2)	13,160	10,400 – 12,990
Disease management	rotate	Mixed

DISCUSSION

Benchmarking can be used to partition yield variability into environmental and management factors. Rainfall and temperature data would suggest it is unlikely growers on the Liverpool Plains could reliably achieve 7 t/ha durum crops. Paddock monitoring has suggested there are a number of management issues that need to be addressed if growers are to achieve yields higher than 5 t/ha.

The WHEATMAN benchmarks for wheat (Table 1) can be broadly applied across the northern NSW cropping zone. Our results from the 1999 season suggest the values will be highly useful; however some adjustment may be necessary. The number of grains/ha should probably be reduced as durum grain is heavier than bread wheat grain (5). Plant populations were generally low, however yields were still relatively high. The longer growing season in the Liverpool Plains may allow later tillers to contribute significantly to crop yield. However, it is still likely that higher plant populations would be required to target high durum yields. Although the rates of fertiliser N used on the Liverpool Plains have increased dramatically in the last five years (2), our results suggest they may still be insufficient for production of high-protein, high-yielding durum.

Using the benchmarks for water use as a guide, soils with a full profile hold only enough water (>200 mm) to enable crops with a yield potential around 7 t/ha to reach flowering. An additional 200 mm (assuming 100% crop use) would still be required to finish the crop. Average in-crop rainfall (mid-June to mid-November) ranges from 200 to 250 mm across the Liverpool Plains (1). From water-use alone, it would be difficult to achieve very high durum yields on a regular basis.

CONCLUSIONS

Low plant population resulting from poor seed quality, insufficient nitrate supply and disease appeared to be major factors limiting durum yields in the monitored crops (range 4.3-5.3 t/ha). Research will focus on gaining further insight into the relationship between the identified soil and plant parameters that determine yield in the Liverpool Plains. Paddock data will be used to initialise simulation modelling to estimate likely risks and returns associated with attempting to target different yields.

Participatory research has the potential to not only highlight possible areas for more detailed component research, but also to identify differences between researcher knowledge and farmer application. These results reinforced the importance of seed quality to farmers. Consequently 90% of farmers in the three groups obtained germination tests for seed (including barley and pulses) used in the 2000 season.

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REFERENCES

1. Clewet, J.F., Smith, P.G., Partridge, I.J., George, D.A. and Peack, A. 1999. Australian Rainman Version 3: An integrated software package of Rainfall Information for Better Management. QI98701, Department of Primary Industries Queensland

2. Hayman, P.T. and Alston, C.L. 1999. A survey of farmer practices and attitudes to nitrogen management in the northern New South Wales grains belt. Aust. J. Exp. Agric. **39**, 51-63

3. Herridge, D.F., Marcellos, H., Felton, W.L., Turner, G.L. and Peoples, M.B. 1995. Chickpea increases soil-N fertility in cereal systems through nitrate sparing and N_2 fixation. Soil Biol. Biochem. **27**, 545-551.

4. Lacy, J.M. 1998. Learning from farmers – the check approach. *Proceedings 9th Australian Agronomy Conference*, Wagga Wagga, 1998. Pp. 58-65.

5. McRae, F.J. 1999. Winter Crop Variety Sowing Guide 2000. NSW Agriculture.

6. Woodruff, D.R. 1992. 'WHEATMAN' a decision support system for wheat management in tropical Australia. Aust. J. Agric. Res. **43**, 1483-1499.

7. Woodruff, D. R. 2000 :WHEATMAN version 6. Decision support and Paddock analysis program for Northern Wheat Regions of Australia. Queensland Department Primary Industries.