**Wheat responses to nitrogen and phosphorus application in the semi-arid environment of central Queensland**

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Summary. Nitrogen (N) application increased wheat. Triticum aestivum cv. Hartog, grain yield (GY) significantly (P<0.05) at 6 of I I sites examined in Central Queensland in 1990; the largest yield increase was 52%. Only at 2 sites, GY responded to P application. Without N fertiliser, grain protein (GP) concentrations were low (range 7.3-10.4%), and N addition improved GP at all the sites but one. The highest GP concentration recorded was 11.7% with 75 kg N/ha. The benefit/cost ratio of using N fertiliser was >1 at 8 sites, including 3 sites where the ratio was >4. This study shows the potential economic benefits of using N fertiliser.

**Introduction**

Declining soil fertility in Central Queensland has caused a downward trend in wheat grain protein (GP) concentrations (1). The percentage of Australian Hard (GP 11.5-12.9%) and Prime Hard (GP >13%) wheat downgraded to Australian Standard White (GP <11.5%) steadily increased from 26% in 1986/87 to 65% in 1990/91 for the Central Highlands and from 7% to 63% for the CallideDawson regions (2). Wheat GP concentrations as low as 6% have been recorded in the region.

On recently cleared land, crops rarely respond to fertiliser due to the high fertility status of the soil. After 5-20 years of cropping, grain yield (GY) responses to fertiliser may occur but are uncertain and often uneconomic (4). In soils that have been cultivated for 30 years or more, N and P deficiencies are emerging regularly in the region. On some farms, reduced mineralisation rates for some elements (e.g., N) are insufficient to meet crop demands not only in good rainfall seasons but also under quite dry conditions. In general, N and P deficiencies are masked to a large extent by the low rainfall (3).

**In 1990, wheat GY and GP responses to N and P application were investigated in the region.**
**Methods**

Eleven sites selected to represent different environments in the region were: Clermont, Capella, Fernlees, Gindie, Orion I, Orion 2, Biloela, Bauhinia Downs, Jambin, Moura and Theodore. Some characteristics of the 6 fertiliser-responsive sites are given in Table I.

Immediately prior to sowing, 4 rates of N (0, 25, 50 and 75 kg N/ha applied as urea) were topdressed, and incorporated into the soil at sowing. An additional treatment consisted of 50 kg N/ha (top dressed) plus 20 kg P/ha (triple superphosphate banded with the seed).

Hartog wheat was sown at all the sites on a full profile of water between mid April to early June 1990. Plots were 13x1.61 m, comprising 7 rows which were 23 cm apart, with 4 replications. Plant density was close to 100 plants/m2. Most sites received moderate (e.g., 37 mm at Capella) to good (>70 mm) follow up rain within 4 weeks of sowing wheat. However, Jambin received no effective rainfall (only 14 mm) during crop growth. The Biloela trial was irrigated close to anthesis. At maturity, GY was measured from the middle 5 rows, each 10 m long, by using a mechanical harvester.

**Results**

At 6 of the II sites, N application increased wheat GY significantly (Table 2; only responsive sites are shown). At 3 sites (Theodore, Biloela and Jambin) where wheat did not respond to N fertiliser, no effective rainfall had fallen within 6 weeks of planting.

At Capella, Femlees, Gindie and Clermont, the highest increases in GY due to N application were 52%, 49%, 43% and 19%, respectively (Table 2). The corresponding soil NO3-N levels were 27, 30, 31 and 39 kg/ha (Table 1). For the 6 responsive sites, GY and GP were positively affected by soil N fertility. At 4 of those sites, GY tended to plateau at 50 kg N/ha rate; at Gindie responses may have occurred at rates >75 kg N/ha.

**Table 1. Characteristics of six trial sites; composition of 0-10 cm layer.**

| Site | Soil type[a] | Rainfall (mm)[b] Preceding 3 months | In-crop | Soil pH (1:5) | Bicarb-P (Colwell) (mg/kg) | Organic C (%) | Total N (%) | $NO_3$-N 0-60 cm (kg/ha) |
|---|---|---|---|---|---|---|---|---|
| Clermont | Ug5.32 | 369 | 133 | 8.01 | 21 | 0.93 | 0.112 | 38 |
| Capella | Ug5.1 | 252 | 50 | 8.39 | 16 | 1.05 | 0.095 | 27 |
| Gindie | Ug5.32 | 263 | 139 | 8.09 | 32 | 1.33 | 0.148 | 31 |
| Fernlees | Ug5.3 | 392 | 101 | 8.33 | 37 | 1.41 | 0.114 | 30 |
| Orion 1 | Ug5.36 | 261 | 174 | 8.39 | 37 | 1.58 | 0.157 | 51 |
| Bauhinia | Ug5.35 | 346 | 97 | 8.15 | 64 | 1.45 | 0.173 | 40 |

[a] All soils were Vertisols and Brown clay except Orion 1 which was Red clay.
[b] Other sites rainfall (mm): Preceding 3 months (In-crop), Moura= 236 (130), Theodore= 210 (85), Biloela= 256 (62) and Jambin= 229 (14).

GP concentrations were low at all the sites. The highest GP recorded was 11.7% at Clermont with 75 kg N/ha (Table 2). GP concentrations <8% were recorded at Capella and Femlees. N application increased GP at all the sites except Theodore. N removal in grain ranged between 30 and 100 kg/ha (Table 2).

Despite large dry matter responses at tillering and anthesis at several sites (data not shown), only Clermont and Moura showed significant GY responses to P addition. Available soil P (Colwell) concentrations were higher than the 10 mg/kg critical level at all the sites. Averaged over II sites, N application alone or with P improved wheat GY and GP concentrations (Table 2).

In monetary terms, benefit/cost ratio of applying N fertiliser was greater than I at 8 of the 11 sites (Table 2; not all sites shown); at 3 sites, the ratio was >4.

## Discussion

Nutrient supply and soil water are highly interactive in determining crop yields (4) and much of the response to fertiliser in the region is a reflection of the quantity of rainfall received. In our study, excluding data from the Biloela site which had received one irrigation, the relationship between GY of the unfertilised control plots (Y) and in-crop rainfall (X) was:

Y = 1911.15 + 15.52 X; r2= 0.663** (P<0.041, n-2 = 8)

Therefore, wheat GY increased as water supply improved. Under our trial conditions, a wheat crop grown on only stored soil water would have produced 1.9 t/ha GY. On an individual paddock, expected GY will depend on many factors (e.g., plant available soil water, soil fertility, crop management, climate). From our study, it appears that if wheat is planted on a full profile of water in Vertisols, there is a reasonable probability of obtaining an economic return from low to moderate rates (-25 kg N) of N fertiliser.

Even though soil NO3-N levels were considered low to very low (27-51 kg/ha; Table 1), GY responses to N fertiliser application did not occur at all the sites, perhaps due to soil water limitations. Fertiliser addition improved water use efficiency (WUE) (Table 2).

**Table 2. Effects of N and P application on wheat grain yield, grain protein, N removal in grain, water use efficiency (WUE) and benefit/cost ratio at 6 responsive sites.**

| | Site | Element (kg/ha) | Yield[b] (kg/ha) | Protein[b] (%) | N uptake (kg/ha) | WUE[a] (kg/ha/mm) | Benefiot/cost ratio[d] |
|---|---|---|---|---|---|---|---|
| 1. | Clermont | N0 | 4540 | 10.0 | 72.6 | -[c] | 1.0 |
| | | N25 | 4850 | 10.8 | 83.8 | - | 1.8 |
| | | N50 | 5160 | 11.2 | 92.5 | - | 1.8 |
| | | N75 | 5420 | 11.7 | 101.4 | - | 1.6 |
| | | N50/P20 | 5580 | 10.9 | 97.2 | - | 1.2 |
| | | l.s.d. (P=0.05) | 392 | 0.52 | - | - | - |
| 2. | Capella | N0 | 2780 | 7.6 | 33.8 | 16.3 | 1.0 |
| | | N25 | 3660 | 7.8 | 45.6 | - | 4.9 |
| | | N50 | 4120 | 8.2 | 54.0 | - | 3.7 |
| | | N75 | 4220 | 8.8 | 59.4 | - | 2.7 |
| | | N50/P20 | 4340 | 8.4 | 58.3 | 25.4 | 1.8 |
| | | l.s.d. (P=0.05) | 377 | 0.29 | - | - | - |
| 3. | Gindie | N0 | 4230 | 9.4 | 63.6 | 18.5 | 1.0 |
| | | N25 | 5130 | 9.9 | 81.3 | - | 5.1 |
| | | N50 | 5650 | 10.2 | 92.2 | - | 4.0 |
| | | N75 | 6050 | 10.2 | 98.7 | - | 3.4 |
| | | N50/P20 | 5790 | 9.7 | 89.9 | 25.2 | 1.8 |
| | | l.s.d. (P=0.05) | 378 | 0.58 | - | - | - |
| 4. | Fernlees | N0 | 2650 | 7.2 | 30.6 | 12.2 | 1.0 |
| | | N25 | 3510 | 7.5 | 42.1 | - | 4.8 |
| | | N50 | 3950 | 8.9 | 56.2 | - | 3.6 |
| | | N75 | 3960 | 9.5 | 60.2 | - | 2.4 |
| | | N50/P20 | 3900 | 8.4 | 52.4 | 17.8 | 1.5 |
| | | l.s.d. (P=0.05) | 468 | 0.50 | - | - | - |
| 5. | Orion 1 | N0 | 5030 | 9.8 | 78.8 | 19.2 | 1.0 |
| | | N25 | 5330 | 9.4 | 80.0 | - | 1.7 |
| | | N50 | 5630 | 9.7 | 87.3 | - | 1.7 |
| | | N75 | 5310 | 10.0 | 84.9 | - | 0.5 |
| | | N50/P20 | 5660 | 10.3 | 93.2 | 20.8 | 0.7 |
| | | l.s.d. (P=0.05) | 570 | 1.21 | - | - | - |
| 6. | Bauhinia Downs | N0 | 3830 | 9.21 | 57.5 | 22.3 | 1.0 |
| | | N25 | 4160 | 9.48 | 67.2 | - | 1.9 |
| | | N50 | 4320 | 9.89 | 72.6 | - | 1.4 |
| | | N75 | 4380 | 10.32 | 77.0 | - | 1.0 |
| | | N50/P20 | 4350 | 9.92 | 75.2 | 24.7 | 0.6 |
| | | l.s.d. (P=0.05) | 295 | 0.18 | - | - | - |
| 7. | Means of 11 sites | N0 | 3750 | 9.21 | 55.8 | 17.9 | - |
| | | N25 | 4140 | 9.48 | 63.3 | - | - |
| | | N50 | 4330 | 9.89 | 69.2 | - | - |
| | | N75 | 4380 | 10.32 | 72.8 | - | - |
| | | N50/P20 | 4470 | 9.92 | 71.5 | 21.7 | - |
| | | l.s.d. (P=0.05) | 97 | 0.18 | - | - | - |

[a] WUE = Grain yield/{[(%$H_2O$ at sowing -%$H_2O$ at harvest) x Bulk density] + In-crop rainfall};
[b] Adjusted to 12% moisture content; [c] = not determined; [d] Benefit/Cost Ratio calculations are based on 1990 urea price of $0.82/kg N, triple superphosphate price of $2.84/kg P, and wheat price of $115/tonne.

GP concentrations were always less than the standard required for Prime Hard quality wheat. Paddocks consistently producing wheat with a GP concentration <11.5% are acutely N deficient and GY response to N addition is likely in almost every year (2). Generally small increases in GP with N application suggest that very large doses of fertiliser would be required before any significant increases in GP can be expected. Improvements to GP concentrations may depend more on a long-term N replenishment strategy rather than a one-off application.

The poor response of GP to N fertilisation at several sites, coupled with small GY response at some sites, suggests poor utilisation of the N fertiliser by the crop. In a 15N experiment by one of the authors (RDA) at Capella in 1990, recovery of N (applied as ammonium nitrate at the rate of 50 kg N/ha) by wheat was only 8% under dryland conditions and 34% under irrigation.

The increased N removal due to fertiliser application was less than the amount of N applied at all the sites except Capella at 75 kg N/ha rate (Table 2). N removed in grain exceeded N inputs from fertiliser, making the system unsustainable. Whereas this N deficit can be made up by organic matter decomposition in recently cleared land. mineralisation rates will inevitably decline with time under nutrient exploitative conditions. Grain producers will then be confronted with the options of (a) high inputs of N fertiliser, (b) leguminous input of N, and (c) change in land use from grain production to a less intensive system of soil N exploitation such as grazing.

We recommend that farmers establish fertiliser strips regularly on their farms, and monitor GP concentrations from different paddocks to determine the effectiveness of fertiliser application programs.

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