Queensland Journal of Agricultural and Animal Sciences Vol. 44 (1), 1-8 (1987)
Published by the Queensland Department of Primary Industries

Effect of pasture on subsequent wheat crops on a black earth soil of the Darling Downs. III. Comparison of nitrogen from pasture and fertiliser sources

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Abstract

In the last two years of an eleven year pasture–wheat rotation experiment, 1967 and 1968, all plots growing wheat were split to permit the application of four rates of nitrogen fertiliser as urea.

A comparison was made between the nil fertiliser sub-plots of the rotation treatments and the fertilised sub-plots of the continuous wheat treatment.

It was shown that the application of nitrogen fertiliser was unable to nullify differences due to previous pasture, in grain yield, dry matter production, grain protein per cent and grain N uptake.

The inefficiency of fertiliser nitrogen compared to pasture nitrogen was attributed to a better profile distribution of pasture nitrogen.

INTRODUCTION

In Littler (1984) and Whitehouse and Littler (1984) the capacity of a lucerne–prairie grass pasture to improve the nitrogen nutrition of subsequent wheat crops was confirmed. This was based mainly on data from the first nine years of the experiment (1958–66).

Because of the increasing usage of nitrogen fertiliser on the Darling Downs, a split-plot design was superimposed on the trial in 1967. This was done to compare the effects of pasture produced soil nitrogen with those of fertiliser nitrogen. Moreover, rotation histories had provided a range of soil nitrate levels within the one site over which responses to nitrogen fertiliser could be compared.

This paper reports the split-plot phase of the experiment.

MATERIALS AND METHODS

Field experiment

The experiment is described in detail by Littler (1984). Briefly, prior to 1967 the experiment had a 9×4 randomised block design with rotation treatments as shown in Table 1. In 1967 all plots sown to wheat were split into four sub-plots and urea was applied at planting at rates of 0, 33, 67 and 101 kg N/ha. The harvested area of each sub-plot was 0.008 ha.

In 1968 urea was re-applied at the same rates to the same sub-plots as in 1967 and was applied for the first time to Treatment 3, which in 1967 had been under pasture.

Planting, urea application and spraying for wild oat control were carried out simultaneously with a 12 run combine. Urea was applied down tubes to the front cultivating tynes while Avadex B.W.® (triallate) was surface sprayed in front of the sowing tynes.

Plots were harvested with a Claas Uropa header and 500 g grain samples taken for percentage protein determination.

Table 1. Key to treatments

Treatment No	Year										
	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
1	W	W	W	W	P	P	P	P	W	W	W
2	P	W	W	W	W	P	P	P	P	W	W
3	P	P	W	W	W	W	P	P	P	P	W
4	P	P	P	W	W	W	W	W	W	W	W
5	P	P	P	P	W	W	W	W	W	W	W
6	W	P	P	P	P	W	W	W	W	W	W
7	W	W	P	P	P	P	W	W	W	W	W
8	W	W	W	P	P	P	P	W	W	W	W
9	W	W	W	W	W	W	W	W	W	W	W

W=Wheat P=Pasture

Plant parameters recorded

Four plant parameters were recorded as measures of the effect of pasture and nitrogen fertiliser on wheat growth. They were:

grain yield (t/ha);
dry matter production at soft dough (t/ha);
grain protein (% protein at 13.5% moisture); and
grain N uptake (kg N/ha).

Dry matter yields were assessed on 0.84 m^2 quadrat cuts taken at the soft dough stage. In 1967 we took two quadrats per sub-plot and in 1968, one.

Soil sampling and analysis methods

In both years soil sampling for nitrate–N was carried out prior to sowing. In 1967 each whole plot was sampled, while in 1968 each nil N sub-plot was sampled.

Soil samples comprised composites of three cores per plot or sub-plot and were taken in 15 cm increments to 60 cm. These were air dried and ground, extracted with lN KCl (1:5) and analysed for nitrate nitrogen (NO_3–N) using the steam distillation procedure of Bremner and Keeney (1966).

Where required for comparisons with weights of fertiliser N, ppm NO_3–N (0 to 60 cm) values were converted to kg N/ha using the measured mean 0 to 60 cm bulk density for the site of 1.00. There were no differences in bulk densities between treatments.

RESULTS

No significant nitrogen fertiliser effects were obtained in grain yield or dry matter yield beyond the lowest N addition (33 kg N/ha). In percentage protein and grain N uptake, only continuous wheat, Treatment 9, showed small but significant increases up to 67 kg N/ha.

For this reason results are presented as −N and +N treatments, with +N being the means of the 33, 67 and 101 kg N/ha rates.

Grain yield, dry matter yield at soft dough, percentage grain protein, grain N uptake and pre-planting soil NO_3–N (mean of 0 to 60 cm) are shown for 1967 in Table 2 and for 1968 in Table 3. Profile distributions of soil NO_3–N for 1967 and 1968 are shown in Table 4. The results of all nitrogen fertiliser rates on continuous wheat, Treatment 9, are shown in Table 5.

1967 results

Fertiliser N effects

Table 2 shows that, in grain yield and dry matter production, significant ($P<0.05$) responses to applied N were limited to Treatment 9, continuous wheat. However, applied N produced significant increases in grain protein in all rotation treatments except in the first crop after pasture, Treatment 2. Effects of fertiliser nitrogen on grain N uptake were inconsistent over rotation treatments, but the most marked increase was in Treatment 9.

Rotation treatment effects

In the absence of applied nitrogen, the continuous wheat treatment (Treatment 9) had a lower yield than all other rotation treatments. Moreover, in the presence of applied nitrogen, Treatment 9 grain yield was still significantly ($P<0.05$) lower than those of the lst, 2nd, 3rd and 6th crops following pasture (Treatments 2, 1, 8, 5; Table 2).

Table 2 shows that similar results were recorded for the other three plant parameters. In general, without applied nitrogen, continuous wheat was significantly ($P<0.05$) lower than rotation treatments. The application of nitrogen fertiliser modified but did not eliminate the differences due to the pasture phase.

Table 2. Grain yield, dry matter production at soft dough, grain protein, grain nitrogen uptake and preplanting soil nitrate for 1967

Treatment		Grain yield (t/ha)		Dry matter at soft dough (t/ha)		Grain protein at 13.5% moisture (%)		Grain N uptake (kg/ha)		Pre-planting soil nitrate–N 0–60 cm depth ppm (kg/ha)
		−N	+N*	−N	+N	−N	+N	−N	+N	−N
1 2nd yr. wheat	. . . .	2.04	2.20	5.52	5.94	12.5	12.9	44.6	49.5	23.0 (138)
2 1st yr. wheat	. . . . . .	2.32	2.29	6.24	6.05	13.7	13.7	55.5	54.9	35.8 (215)
3 4th yr. pasture	. . . .	-	-	-	-	-	-	-	-	20.2 (121)
4 7th yr. wheat	. . . . . .	2.10	2.10	5.11	5.44	12.1	12.5	44.5	46.2	11.5 (69)
5 6th yr. wheat	. . . . . .	2.23	2.20	5.16	5.58	12.0	12.5	46.8	48.0	10.5 (63)
6 5th yr. wheat	. . . . . .	2.03	2.11	4.68	5.06	12.0	12.5	42.7	46.3	11.4 (68)
7 4th yr. wheat	. . . . . .	2.07	2.16	5.20	5.64	12.1	12.6	44.2	47.5	10.6 (64)
8 3rd yr. wheat	. . . . . .	2.22	2.34	5.74	5.47	12.2	12.6	47.5	51.6	14.7 (88)
9 Cont. wheat	. . . . . .	1.69	2.05	4.00	5.06	10.8	12.0	31.9	43.2	7.3 (44)
LSD vert.	P=0.05	0.21	0.12	0.74	0.42	0.4	0.2	4.6	2.7	3.0 (18)
LSD horiz.	P=0.05	0.17		0.53		0.2		3.4		

*+N are means of 33, 67 and 101 kg N/ha rates.

1968 results

While the 1967 season may be described as finishing well after a dry start the 1968 season started with good rains but was marred by a severe heat wave during grain fill. This caused severe haying-off of the crop and the production of pinched, low density grain.

These seasonal conditions were reflected in reduced yields and higher protein levels relative to 1967.

As shown by Table 3 there were no grain yield responses to applied nitrogen in 1968. In general the trends obtained in 1967 were repeated in 1968 but were not as well defined.

Table 3. Grain yield, dry matter production at soft dough, grain protein, grain nitrogen uptake and preplanting soil nitrate for 1968

Treatment	Grain yield (t/ha)		Dry matter at soft dough (t/ha)		Grain protein at 13.5% moisture (%)		Grain N uptake (kg/ha)		Pre-planting Soil NO3–N 0–60 cm depth bin nil N sub-plots ppm (kg/ha)
	−N	+N*	−N	+N	−N	+N	−N	+N	−N
1 3rd yr. wheat	1.89	1.71	4.73	5.11	14.4	15.3	47.6	46.0	21.9 (131)
2 2nd yr. wheat	1.35	1.46	4.25	4.54	15.6	16.1	37.0	41.3	29.0 (174)
3 1st yr. pasture	1.64	1.53	6.18	6.20	17.2	17.5	49.3	46.8	36.3 (218)
4 8th yr. wheat	1.53	1.55	4.13	4.64	13.3	15.6	35.6	42.4	9.9 (60)
5 7th yr. wheat	1.59	1.50	4.98	4.54	13.6	15.7	38.0	41.2	13.7 (82)
6 6th yr. wheat	1.70	1.57	5.13	4.90	13.3	15.3	39.7	42.2	11.7 (70)
7 5th yr. wheat	1.66	1.63	4.28	4.79	13.8	15.5	40.2	44.2	9.6 (58)
8 4th yr. wheat	1.67	1.58	4.81	4.82	14.4	15.4	42.1	42.6	13.9 (83)
9 Cont. wheat	1.58	1.57	3.70	4.82	11.9	15.2	32.9	41.8	7.3 (44)
LSD vert. P=0.05	0.18	0.10	0.68	0.39	0.7	0.4	5.0	2.9	3.4 (20)
LSD horiz. P=0.05	n.s.†		0.55		0.6		3.6		

*+N are means of 33, 67 and 101 kg N/ha rates.

†n.s.=not significant.

Table 4. Pre-planting soil nitrate–N (ppm) at 0 to 15, 15 to 30, 30 to 45 and 45 to 60 cm depth intervals in 1967 and at 0 to 15, 15 to 30 and 30 to 60 cm depth intervals in 1968

Treatment no	1967					1968			
	Treatment	0–15	15–30	30–45	45–60	Treatment	0–15	15–30	30–60
1	2nd yr. wheat	29.0	23.6	21.0	19.5	3rd yr. wheat	6.7	24.0	28.5
2	1st yr. wheat	30.0	43.5	42.3	41.0	2nd yr. wheat	6.9	27.1	41.0
3	4th yr. pasture	-	-	-	-	1st yr. wheat	6.5	54.8	41.9
4	7th yr. wheat	13.4	11.1	10.8	11.5	8th yr. wheat	4.7	13.9	10.6
5	6th yr. wheat	12.6	11.0	10.1	8.1	7th yr. wheat	7.0	14.6	16.6
6	5th yr. wheat	13.8	11.7	10.1	9.9	6th yr. wheat	4.0	15.6	13.6
7	4th yr. wheat	11.9	10.8	9.7	10.6	5th yr. wheat	3.6	14.2	10.4
8	3rd yr. wheat	16.2	15.0	13.4	14.4	4th yr. wheat	6.2	17.8	15.8
9	Cont. wheat	9.0	7.6	6.6	6.0	Cont. wheat	3.1	10.2	7.9
	LSD P=0.05	6.9	5.0	2.4	2.2		3.2	9.6	7.4

Table 5. Fertiliser nitrogen results for Treatment 9 (continuous wheat)

Fertiliser N applied (kg/ha)	Yield (t/ha)		Dry matter (t/ha)		Protein % (at 13.5% Moist)		Grain N uptake (kg/ha)	
	1967	1968	1967	1968	1967	1968	1967	1968
0	1.69	1.58	4.00	3.70	10.9	11.9	31.9	33.3
33	2.00	1.54	5.16	4.53	11.7	14.7	41.6	39.5
67	2.14	1.56	5.00	5.04	12.1	15.6	45.6	42.4
101	2.01	1.63	5.01	4.91	12.1	15.2	42.8	43.5
LSD P=0.05	0.21	0.18	0.74	0.68	0.4	0.7	4.6	2.9

Table 6. 1967 regressions of plant parameters on soil and soil+fertiliser nitrogen using the regression model *Y=a+bcx*

y	*x*	*a*±SE	*b*±SE	*c*±SE	R^2
Nil–N sub-plots over 8 rotation treatments (n=32)					
Grain yield (t/ha)	kg N/ha as	2.1931±0.1004	−0.8126±1.238	0.9718±0.0300	0.106
Dry matter yield (t/ha)	NO_3–N sampled	6.068±0.280	−4.487±1.724	0.9780±0.0090	0.515**
Grain protein %	pre-planting to 60 cm	14.64±1.45	−4.29±0.98	0.9936±0.0048	0.709**
Grain N uptake (kg/ha)	depth	55.22±7.76	−24.31±6.36	0.9898±0.0104	0.357**
Continuous wheat treatment over 4 fertiliser N rates (n=16)					
Grain yield (t/ha)	kg N/ha as	2.082±0.212	−0.7820±1.1240	0.9760±0.0446	0.176
Dry matter yield (t/ha)	NO_3–N	5.074±0.279	−5.031±3.683	0.9594±0.0265	0.453**
Grain protein %	Treatment 9 +kg N	12.23±0.16	−5.58±0.92	0.9684±0.0101	0.843**
Grain N uptake (kg/ha)	applied as urea	44.67±4.04	−32.37+8.096	0.9736±0.0264	0.398**

** Regression significant ($P<0.01$).

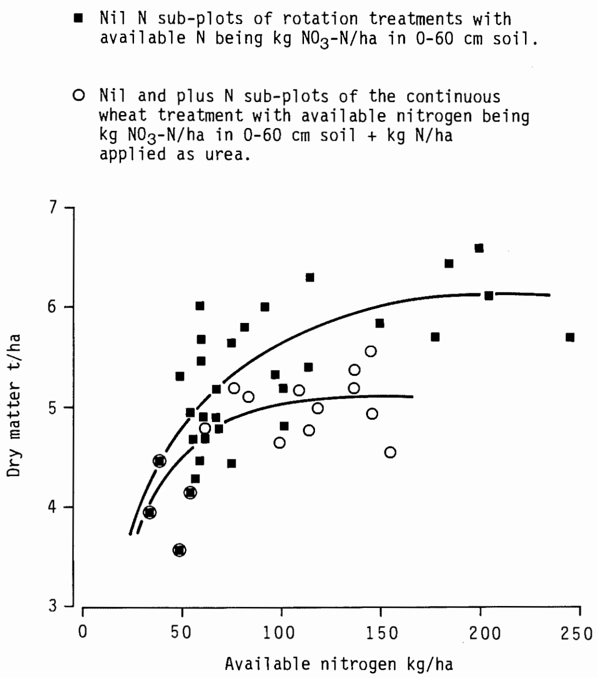

Figure 1. Relationship between dry matter yield and available nitrogen. Equation to fitted curves show in Table 6.

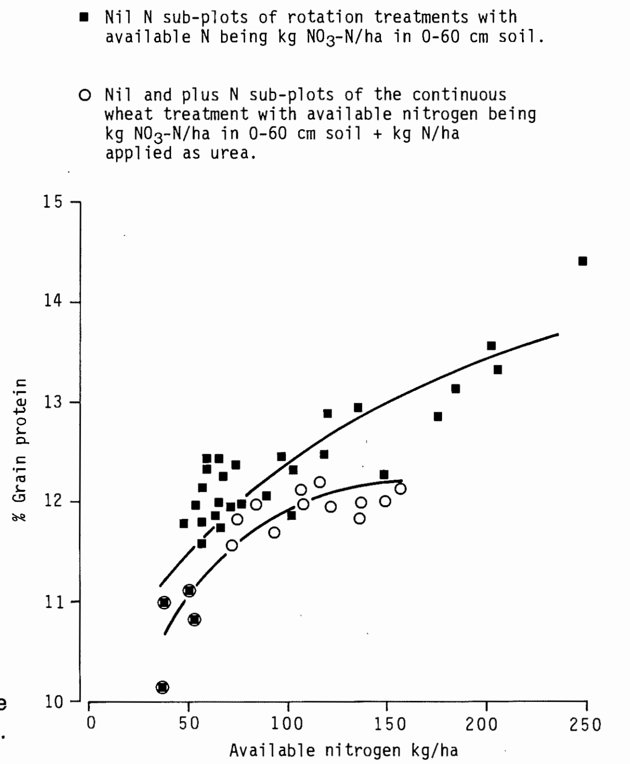

Figure 2. Relationship between per cent grain protein and available nitrogen. Equations of fitted curves shown in Table 6.

Relative response to pasture-produced nitrogen and fertiliser nitrogen

In order to compare the effects of pasture-produced N and fertiliser N, using 1967 data, regressions were fitted to the nil N sub-plot data over all main treatments and to the continuous wheat treatment over all fertiliser nitrogen rates.

Main treatments plant parameters were regressed on kg N/ha as NO_3–N measured to 60 cm depth, and fertiliser rates plant parameters were regressed on kg N/ha as NO_3–N in Treatment 9 plus kilograms of nitrogen applied as fertiliser. The regression model used was an exponential of the form $Y=a+bc^x$ which was fitted iteratively.

Regressions obtained from the 1967 data are shown in Table 6. The two plant parameters showing most clearly the relative effects of soil and fertiliser N are, dry matter production and percentage protein. These relationships are illustrated in Figures 1 and 2.

DISCUSSION

Many workers, both in Australia and overseas, have shown that previous pasture can improve the yield and protein content of subsequent wheat crops (Rixon 1961; Tucker, Cox and Eck 1971). Such improvements are usually attributed to improved soil nitrogen supply resulting from the pasture.

In this experiment there is no doubt that old pasture plots, even after seven wheat crops, have a higher nitrogen status than continuous wheat plots (Whitehouse and Littler 1984). Moreover, regressions in Table 6 indicate that improvements in dry matter production, grain protein and grain N uptake were related to differences in soil nitrate status.

In 1967 (Table 2) grain yield and dry matter responses to applied nitrogen occurred when 0 to 60 cm soil NO_3–N levels were 7.3 ppm (44 kg N/ha) but were absent at 10.5 ppm (63 kg N/ha). This suggests a critical soil nitrate range of 7.5 to 10 ppm (45 to 60 kg N/ha) based on 0 to 60 cm sampling. The same critical soil test range could be applied to dry matter responses in 1968. However, severe finishing conditions in that season prevented any grain yield responses even at the lowest soil NO_3–N level (Table 5).

The critical soil test range for grain protein responses to applied N were much higher, in that 25 to 30 ppm NO_3–N (150 to 200 kg N/ha) was needed to preclude fertiliser N response in grain protein content (Table 2).

There are few publications in Australia on nitrogen responses in wheat yield in relation to soil nitrate levels. Nitrogen fertiliser experiments on wheat in Queensland showed that few grain yield responses occurred on soils with greater than 80 kg NO_3–N/ha in 0 to 60 cm soil (unpub. data, Queensland Wheat Research Institute).

Taylor, Storrier and Gilmour (1974) found from a study of factors affecting control yields in a series of nitrogen trials in NSW, that levels of 20 ppm NO_3–N in 0 to 30 cm soil set a sharp limit on grain yield potential. In another paper (Taylor, Storrier and Gilmour 1978) they suggest from the same data that responses to applied nitrogen would be economical on soils of less than 8 ppm NO_3–N in 0 to 30 cm provided rainfall is adequate.

In our comparison of pasture effects and fertiliser N we have shown that the application of nitrogen fertiliser has not been able to raise grain yield and dry matter production of continuous wheat to the level obtained in treatments previously growing pasture (Table 2, Figure 1).

These results suggest, at least in this season, that native soil mineral nitrogen is more available than applied fertiliser nitrogen. This can possibly be explained on the basis of a more even profile distribution of native soil nitrate (Table 4) compared with the profile mineral N distribution we would expect from fertiliser nitrogen, coupled with dry pre-flowering conditions.

Initial concentrations of mineral N about all fertiliser bands would be high, and early uptake of fertiliser N was probably limited by the ability of roots to absorb the N, regardless of the different concentrations of N produced by the three rates of fertiliser. With rapid drying out of the surface layer, utilisation of N from the fertiliser band would virtually cease, which could explain why yields of wheat levelled out at the lowest fertiliser rate. For continuous wheat, the only rotation treatment that responded to fertiliser N, subsoil nitrate was low (6.7 ppm NO_3–N in 15 to 60 cm in 1967); so it is quite conceivable that maximum yield for this rotation treatment was limited by nitrogen supply even though there was a bountiful source of fertiliser N lying unavailable in the dry surface layer.

With comparisons across rotation treatments, pasture-produced subsoil (15 to 60 cm depth) nitrate N ranged from a low 6.7 ppm to a high 42.3 ppm. Thus the wheat would have access to a wide range of mineral N regardless of surface drying, and yield would attain a maximum limited by factors other than nitrogen supply.

This hypothesis is supported by work of Strong and Cooper (1980) who showed that, on a similar soil and under similar dry pre-flowering conditions, wheat was able to utilise nitrate placed at or below 30 cm better than that placed at 7.5 cm. In our experiment only 45 mm of rain fell during the first 3 months of the crop in 1967, and the maximum single fall of 18 mm was sufficient to wet to a depth of only 5 cm. Under such conditions we would expect the wheat to utilise high pasture-produced nitrate N distributed evenly throughout the profile better than high fertiliser-produced mineral N concentrated in the drier surface layer. There are other possible explanations.

The failure of fertiliser nitrogen to obviate pasture-produced differences may also be attributed to other soil (structure, moisture) or biological (wild oats, root rot) factors:

Soil structure. Bulk density measurements were taken in 1962 and 1964 as a means of evaluating treatment effects on soil structure, but results showed that any differences in bulk density were of a transient nature only (Littler 1984).

Soil moisture. Pre-planting soil samples for moisture assessment were taken in most years and showed there were virtually no differences among rotation treatments (Littler 1984).

Wild oat population. This was greatest on the continuous wheat plots but insufficient to materially effect yield (Littler 1984).

Soil pathogens. No differences in root rot incidence were found among rotation treatments (Littler 1984).

All factors considered we feel the first hypothesis (better nitrate distribution) is a more likely explanation than any of the alternatives.

ACKNOWLEDGEMENTS

The Authors thank Mr H. H. Tod for his co-operation during the period of experimentation, on his property at Jondaryan. The assistance of the many officers of the Department of Primary Industries is gratefully acknowledged.

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(Accepted for publication 22 August 1986)