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COMPARISON OF FOUR NITROGENOUS FERTILIZERS FOR TOPDRESSING WINTER OATS ON A DARLING DOWNS SOIL

By G. F. HAYDON, B.Sc. and J. W. LITTLER, B.Agr.Sc.

SUMMARY

Urea, ammonium nitrate, ammonium sulphate and diammonium phosphate were applied at 0, 26 and 52 kg N ha^{-1} to Camellia oats on a Darling Downs black earth during the winters of 1971 to 1973. Dry matter yields and percentage nitrogen in tops were measured and soil samples from the fertilizer treatments were analysed for nitrate and ammonium nitrogen. Urea treatments were also analysed for urea in the soil.

Urea and ammonium nitrate provided the highest dry matter yield increases (478 and 588 kg ha^{-1} respectively) over control, when applied at 52 kg N ha^{-1}. Ammonium sulphate and diammonium phosphate did not significantly increase yields over the same period.

Measurement of soil mineral nitrogen showed that nitrate was produced faster from urea than from ammonium sulphate. The reason for the yield increases measured from urea and ammonium nitrate treatments is presumed to be due to increased nitrification of urea, and also to a preference by oats for nitrogen as nitrate rather than the ammonium form.

I. INTRODUCTION

The practice of topdressing winter oats with nitrogen is widespread on the Darling Downs. Several nitrogen sources are used but little information is available on their relative effectiveness. The aim of this work was to compare the effectiveness of four sources of fertilizer nitrogen applied as topdressing to oats, following the first mowing. The literature from Queensland provides little information on the subject of changes in soil mineral nitrogen during the growth of oats. Therefore, to help interpret results, soil mineral nitrogen from various treatments was monitored during two of the three seasons.

II. MATERIALS AND METHODS

Experiments were sited at the Hermitage Research Station near Warwick in south-east Queensland. A separate site was used each year. The experiments were conducted on a black earth (Stace *et al.* 1968) typical of many soils in the Warwick area used for winter oat production. Surface soil (0 to 10 cm) at each site is a strong, fine to medium, subangular, blocky medium clay containing lime. Dark-brown clay persists to 100 cm over a brown clay containing less lime. Table 4 lists some chemical properties of the soil.

Representative surface (0 to 10 cm) samples were collected at the beginning of each year's experiment, before treatments were applied.

Design and treatments

A randomized block design was used with four blocks of twelve treatments consisting of four fertilizers (urea, ammonium nitrate, ammonium sulphate and diammonium phosphate) each applied at 0, 26 and 52 kg N ha^{-1}.

Plots comprised an area of 3·35 m^2 and strips 2·8 m^2 were used as datum areas.

To overcome confounding effects, phosphorus (as NaH_2PO_4) and sulphur (as Na_2SO_4) were added to appropriate plots to make all plots equivalent to the phosphorus rate used in diammonium phosphate and the sulphur used in ammonium sulphate when the nitrogen rate was 52 kg ha^{-1}. Treatments were applied by broadcasting after mowing the oats to an even 10-cm-high stand. For each experiment, harvesting was done by hand at early heading. Samples were dried at 105°C for 48 h before weighing.

In 1972 and 1973, an additional four plots per block were planted. These were used to monitor soil mineral nitrogen changes in the surface (0 to 10 cm) soil during crop growth. To avoid any effect of soil sampling on yield, monitored plots were not used in yield measurements. Treatments selected were control, urea, ammonium sulphate and ammonium nitrate all at the 52 kg ha^{-1} rate. Diammonium phosphate was excluded because it is the least commonly used form.

These plots were intensively sampled at approximately 7-day intervals from application of fertilizers by taking 16 cores (0 to 10 cm deep, 5 cm diameter) from four areas in each plot. Bulking samples within each area gave a total of four samples per plot for analysis. Samples were transported cold directly to the laboratory and placed in a forced-air draught oven set at 40°C for 48 h then ground to pass a 2-mm sieve prior to analysis.

Chemical analyses

SOILS

Soils were analysed for nitrate nitrogen by the ion selective method of Øien and Selmer-Olsen (1969) and for ammonium nitrogen by the distillation method of Bremner and Keeney (1965) after extraction in 2 N KCl solution using a 1 : 5 soil solution ratio and one hour shaking. Urea was determined colorimetrically by the method of Douglas and Bremner (1970).

PLANTS

Sub-samples of weighed dry matter were ground to pass a 1-mm sieve in a stainless steel mill, dried at 105°C for 10 h then analysed for nitrogen by the Kjeldahl method.

Analysis of variance was used to assess relative effectiveness of fertilizers using dry matter yields and nitrogen uptake data.

Climatic data

Monthly rainfall figures for the 3 years are shown in figure 1 with associated soil temperatures, fertilizing and harvesting dates. Total rainfall in 1972 was one third of the long term average for the Warwick area, while in 1973 the total was 53% greater. 1971 rainfall was close to average. The below average 1972 rainfall was probably the cause of the depressed growth observed.

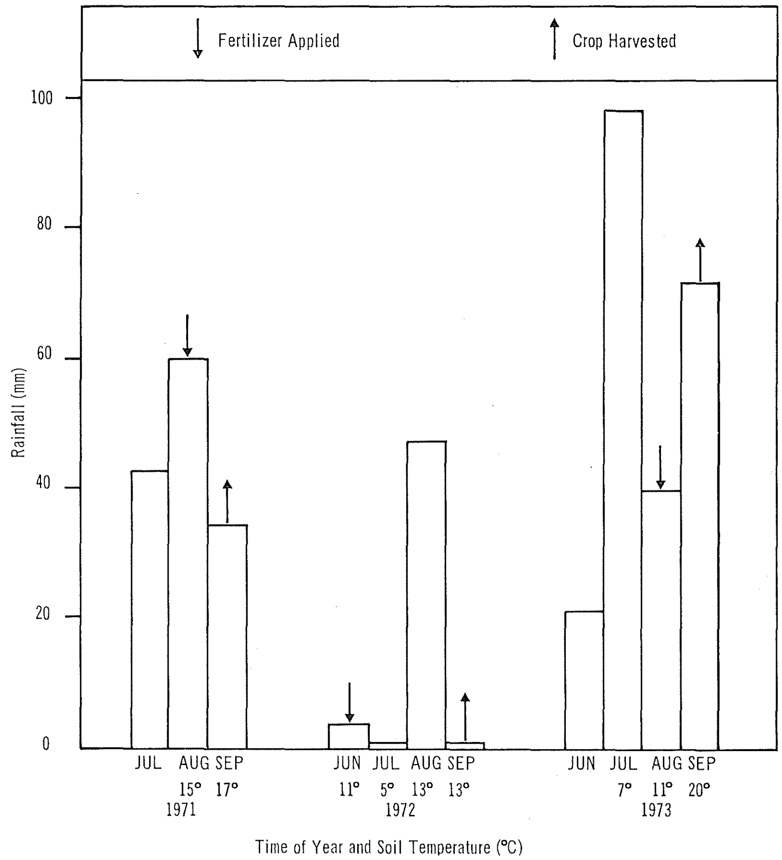

Figure 1. Rainfall distribution, mean soil temperature (°C at 9 a.m., at depth of 15 cm on site), and times of fertilizer application and crop harvesting for three seasons.

III. RESULTS

Dry matter yields

Results are given in table 1. In the three experiments, yield increased with applications of nitrogen up to 52 kg ha^{-1}. The effect of source of nitrogen is shown in table 2. Ammonium nitrate and urea were clearly superior to ammonium sulphate and diammonium phosphate at both rates of nitrogen (3-year-mean data). Compared to unfertilized treatments, urea at the 52 kg N ha^{-1} rate significantly increased ($P < 0{\cdot}05$) dry matter yields in 1971 and 1973 while ammonium nitrate increased yields in each year when applied at the 52 kg ha^{-1} rate.

Diammonium phosphate and ammonium sulphate increased yields significantly only in 1973 and only at the 52 kg N ha^{-1} rate.

Overall, the magnitude of the increases obtained was much greater from urea and ammonium nitrate than from either ammonium sulphate or diammonium phosphate. Thus in 1973, the only year in which responses were obtained from ammonium sulphate and diammonium phosphate, urea increased yields by 563 kg ha^{-1}, ammonium nitrate by 585 kg ha^{-1} while increases from ammonium sulphate and diammonium phosphate were 267 kg-ha^{-1} and 197 kg ha^{-1} respectively.

TABLE 1

EFFECT OF NITROGEN SOURCE AND NITROGEN RATE ON DRY MATTER PRODUCTION, NITROGEN CONCENTRATION AND NITROGEN UPTAKE IN OATS

N Form	N Rate kg ha^{-1}	Dry Matter (kg ha^{-1})				% N				N Uptake (kg ha^{-1})			
		1971	1972	1973	Mean	1971	1972	1973	Mean	1971	1972	1973	Mean
Urea	0	2 119a	726ab	1 276a	1 374a	2·30a	2·04a	2·28a	2·21a	50·5a	15·0ab	29·0a	31·5a
	26	2 512ab	797ab	1 577b	1 629b	2·83b	2·47b	2·95c	2·75c	71·0c	19·0bc	47·0c	46·0c
	52	2 859bc	859b	1 839c	1 852bc	3·06bc	2·75c	3·21d	3·00d	88·4d	23·0c	59·0d	57·0d
Ammonium Nitrate ..	26	2 435ab	806ab	1 574b	1 604a	2·46a	2·60b	2·70b	2·59bc	60·0b	21·0c	43·0bc	41·0bc
	52	2 891c	1 132c	1 861c	1 962c	3·19c	2·92c	3·01cd	3·04d	93·0d	32·0d	56·0d	60·0d
Ammonium Sulphate	26	2 175a	877b	1 460ab	1 503a	2·46a	2·43b	2·59b	2·49b	55·0a	22·0c	37·0b	31·0a
	52	2 225a	801ab	1 543b	1 523a	2·93bc	2·49b	2·76b	2·72c	69·0c	19·0bc	43·0bc	43·0bc
Diammonium Phosphate	26	2 275a	623a	1 436ab	1 444a	2·55a	2·18a	2·67b	2·50b	62·0b	13·0a	38·0b	37·0ab
	52	2 146a	936bc	1 473b	1 519a	2·76b	2·32a	2·83bc	2·64bc	60·0b	22·0c	42·0bc	41·0bc
LSD 5%	..	426	217	189	242	0·37	0·31	0·30	0·19	5·3	5·9	6·3	8·9

Means followed by the same letter are not significantly different.

Nitrogen concentration

Nitrogen concentration in dry matter increased sharply with nitrogen applications up to 52 kg ha^{-1} (table 1) when applied either as urea or ammonium nitrate. However, this rise in concentration was much less when the nitrogen source was either ammonium sulphate or diammonium phosphate. Within treatments there were small differences in nitrogen concentration between years but the 1972 results are lower in all but one treatment.

Nitrogen uptake

Comparing the four sources of nitrogen in terms of recovery of applied nitrogen in dry matter, amounts recovered were greater from ammonium nitrate and urea at both rates of applied nitrogen. Recoveries of nitrogen from ammonium sulphate and diammonium phosphate were much lower (table 2).

TABLE 2

PERCENTAGE RECOVERY OF APPLIED NITROGEN IN TOPS—THREE YEAR MEANS

Fertilizer Source	52 kg N ha^{-1} Rate	26 kg N ha^{-1} Rate
Ammonium nitrate ..	55	37
Urea	49	56
Ammonium sulphate ..	22	0
Diammonium phosphate	18	21

Effect of seasonal rainfall on nitrogen uptake can be estimated by comparing the 1971 and 1972 data for the 52 kg N ha^{-1} rate. In 1971 (average rainfall) increases in nitrogen uptake over control treatments were 37·9 kg ha^{-1} and 42·5 kg ha^{-1} for urea and ammonium nitrate and 18·5 kg ha^{-1} and 9·5 kg ha^{-1} from ammonium sulphate and diammonium phosphate respectively. In the dry 1972 season, overall amounts of recovered nitrogen were about one-third those of 1971. However, the ratio of amount of nitrogen recovered from urea and ammonium nitrate to that recovered from ammonium sulphate and diammonium phosphate was about the same as in 1971, that is about three to one.

Soils

Changes in soil ammonium, nitrate and urea nitrogen on monitored treatments in 1972 and 1973 are listed in table 3. Analyses of soil samples prior to fertilizer application showed that initial soil nitrate and ammonium nitrogen values were uniformly low i.e. 3 to 5 ppm in the 0 to 10-cm depth.

1972 season

Little change in nitrate or ammonium nitrogen concentrations was detected in the urea treatments until 63 days after fertilizer application. At that time of sampling, which occurred 8 days after 21·8 mm of rain, a rapid depletion of urea occurred with a corresponding rise in concentration of nitrate and ammonium nitrogen. These levels persisted until final sampling 80 days from application when the urea concentration in the soil had been depleted.

In ammonium nitrate treatments, nitrate concentration remained steady until 63 days from application, then rapidly declined. Ammonium nitrogen concentration followed a similar but much smaller decline. Analysis of ammonium sulphate treatments showed an expected high ammonium nitrogen concentration but only a small rise in nitrate nitrogen even up to 80 days from application.

TABLE 3

MEAN SOIL NITROGEN DATA FOR MONITORED PLOTS, VALUES IN PPM (0 TO 10 cm)

Days from Application	Control		Urea 52 kg N ha^{-1}			Ammonium Sulphate 52 kg N ha^{-1}		Ammonium Nitrate 52 kg N ha^{-1}	
	NO_3–N	NH_4–N	NO_3–N	NH_4–N	Urea	NO_3–N	NH_4–N	NO_3–N	NH_4–N
1972									
7	5	3	4	6	45	5	50	45	33
18	4	4	4	7	48	5	36	41	28
27	4	3	5	7	41	4	36	30	27
63	5	5	11	40	5	10	60	45	33
80	5	4	14	45	1	8	45	19	25
1973									
7	6	4	16	41	30	8	44	33	15
14	8	2	22	19	8	12	19	25	14
20	5	4	7	9	1	8	10	17	10
28	4	4	10	9	0	11	13	10	10

LSD 5% = 4·5 ppm
1% = 10 ppm

TABLE 4

SOME CHEMICAL CHARACTERISTICS OF THE SOIL TYPE

Soil Depth	Acid Phosphorus ppm 0·005 M H_2SO_4	Bicarbonate Phosphorus ppm 0·5M $NaHCO_3$	pH	Exchangeable Cations (m. equiv. $100g^{-1}$)				CEC	NO_3–N ppm	Cl–ppm
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}			
0–10 cm	120	130	7·5	32	23	0·80	1·71	59	5	40

1973 season

In this year, 21·6 mm of rain fell 4 days after fertilizer application. The first sampling of urea treatments showed some transformation of urea since ammonium and nitrate nitrogen concentrations were well above those observed in 1972 at a similar sampling time.

A later sampling (14 days) showed an accumulation of nitrate while ammonium nitrogen was quickly depleted. By 20 days, urea had almost disappeared and from this time until 28 days when sampling ceased because urea could no longer be detected, ammonium and nitrate concentrations were stable.

In ammonium sulphate treatments, the ammonium form tended to persist, following an initial drop in concentration, while at the same time only a small rise in nitrate was measured. Ammonium nitrate plots had high initial nitrate followed by a decline from 33 ppm to 10 ppm in 28 days. Ammonium concentration remained relatively stable during the same period.

IV. DISCUSSION

Rainfall had a marked effect on availability of the four fertilizers. In 1972, when total rainfall was only one-third that of a normal season, production of nitrate from both urea and ammonium sulphate was slow (table 3) and neither form produced significant yield increases. Some rainfall is necessary to wash fertilizer into the soil and while there may have been enough to make some nitrogen available, only ammonium nitrate produced a small but significant dry matter yield increase. In 1973, a year of good rainfall, 21·6 mm of rain fell 4 days after treatment application and resulted in a greater rate of nitrate production from urea than from ammonium sulphate. This effect of rainfall, and consequently soil moisture, on nitrification seems to be responsible for the better performance of urea compared to ammonium sulphate and probably diammonium phosphate.

These findings are in agreement with those of Whitehouse and Leslie (1973) who found urea to be almost completely nitrified 30 days after application to a black soil similar to that used in our experiments. They also found that after the same period ammonium sulphate was only 50% nitrified and after 90 days only 80% nitrified.

Under the dry conditions of 1972, the response obtained to ammonium nitrate may have been due to a preference for the nitrate form. Under conditions of low soil moisture, wheat can take up nitrate in preference to ammonium nitrogen, while either form is suitable under high soil moisture (Stefanson 1972; Spratt and Gasser 1970). If a similar preference for nitrate under dry conditions exists in oats, then this factor could explain the differences in yield found from the different fertilizer forms especially since large amounts of nitrate were present on ammonium nitrate plots.

Under conditions where ammonium is only slowly oxidised to nitrate, or where a preference for nitrate exists, the efficiency of nitrate fertilizers or of fertilizers which rapidly nitrify may be higher than others. This certainly seems to have been so in these experiments and it is concluded that as a result of these observations, urea and ammonium nitrate are the preferred fertilizers for winter topdressing of oats.

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Mr Haydon is an officer of Agricultural Chemistry Branch stationed at Indooroopilly, Queensland. Mr Littler is an officer of Agriculture Branch stationed at Warwick.