THE EFFECT OF THE NITRIFICATION INHIBITOR ATC ON SOIL MINERAL NITROGEN STATUS AND WHEAT YIELDS

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The objectives of this research, which was conducted during the 1976 growing season, were:

1) To evaluate the effectiveness of the nitrification inhibitor ATC (4-amino-1,2,4-triazole) in controlling the oxidation of ammonium to nitrate by the nitrifying organisms in the soil.

2) To evaluate the ATC coated urea as a source of nitrogen for wheat.

EXPERIMENTAL METHODS

Three experimental plots were selected on stubble fields in the spring of 1976 as follows:

1) Bradwell very fine sandy loam soil. University of Saskatchewan, Goodale Farm, Floral, Saskatchewan (summerfallowed throughout the season).

2) Elstow loam soil. A. Carlson Farm, Outlook, Saskatchewan (irrigated wheat).

3) Melfort silty clay loam soil. Nielson Brothers Farm, Melfort, Saskatchewan (dryland wheat).

Small plots were established using a randomized complete block design at each of the three sites. The details of plot size and treatments used are shown in Tables 1 to 3. At all three sites the nitrogen treatments were applied as a broadcast application and incorporated into the surface soil.

On the Bradwell soil no crop was grown and the plots were cultivated throughout the season to control weed growth and keep the soil in a summerfallowed condition. After the application of the various treatments, soil samples were obtained from the 0-7 cm, 7-15 cm, 15-30 cm and 30-60 cm depths at two week intervals throughout the season. Three cores from each replicate were bulked, the samples were then air-dried and the percent moisture on an air-dry basis determined. After grinding the mixing the air-dried samples, the exchangeable NH_4^+ and NO_3^--N content were determined.

On the Elstow soil, irrigated Neepawa wheat was grown. In addition to the urea and ATC coated urea treatment shown in Table 2, the crop received 30 kg/ha of P_2O_5 applied as 11-55-0 with the seed. Wild oats were controlled by the

Table 1. Treatments used to investigate the effect of the nitrification inhibitor ATC on Soil NO_3^--N and NH_4^+-N levels in a summerfallowed plot.

Treatment No.	kg/ha	Source
1	0	-
2	200 N	Urea with 0.5% ATC
3	200 N	Urea with 2.0% ATC
4	200 N	Urea
5	1.0 ATC	ATC
6	4.0 ATC	ATC

Plot size: 1m x 2m

Design: Randomized complete block with 4 reps

Location: NE 33-35-4 W3, University Goodale Farm

Soil type: Bradwell very fine sandy loam

Date established: May 13, 1976

Table 2. Treatments used to investigate the effect of the nitrification inhibitor ATC on the uptake of fertilizer nitrogen and the yield of wheat under irrigated conditions.

Treatment No.	kg N/ha	Source
0	0	-
1	0	-
2	25	Urea
3	50	Urea
4	100	Urea
5	200	Urea
6	200*	Urea
7	25	Urea with 0.3% ATC
8	50	Urea with 0.3% ATC
9	100	Urea with 0.3% ATC
10	200	Urea with 0.3% ATC
11	25	Urea with 1.0% ATC
12	50	Urea with 1.0% ATC
13	100	Urea with 1.0% ATC
14	200	Urea with 1.0% ATC
15	200*	Urea with 1.0% ATC

*Treatments 0,6 and 15 were for destructive sampling throughout the growing season.

Plot size: 5' x 20'

Irrigation type: Border dike

Design: Randomized complete block with 4 reps

Location: NE 14-27-7 W3 (A. Carlson farm, Cutbank)

Soil type: Elstow loam

Date established: May 14, 1976 (Neepawa wheat)

Table 3. Treatments used to investigate the effect of the nitrification inhibitor ATC on the uptake of fertilizer nitrogen and the yield of wheat under dryland conditions.

Treatment No.	kg N/ha	Source
0	0	-
1	0	0
2	25	Urea
3	50	Urea
4	100	Urea
5	200	Urea
6	200*	Urea
7	25	Urea with 0.3% ATC
8	50	Urea with 0.3% ATC
9	100	Urea with 0.3% ATC
10	200	Urea with 0.3% ATC
11	25	Urea with 1.0% ATC
12	50	Urea with 1.0% ATC
13	100	Urea with 1.0% ATC
14	200	Urea with 1.0% ATC
15	200*	Urea with 0.3% ATC

*Treatments 0,6 and 15 were for destructive sampling throughout the growing season.

Plot size:	5' x 20'
Design:	Randomized complete block with 4 reps
Location:	NE 32-43-19 W2 (Nielson farm, Melfort)
Soil type:	Melfort silty clay loam
Date established:	May 19, 1976 (Neepawa wheat)

farmer using a pre-plant application of Avadex B.W. On treatments 0, 6 and 15 plant and soil samples were collected at five different growth stages throughout the season in order to determine total above ground dry matter production, and yield of nitrogen at tillering, flag leaf, heading, soft dough and maturity. For the other treatments grain and straw yields and their nitrogen content were determined at maturity.

On the Melfort soil, Neepawa wheat was grown. In addition to the urea and ATC treatments shown in Table 3 the crop received 40 kg/ha of P_2O_5 applied as 11-55-0 with the seed. A post emergent spray application of Endaven was used with partial success in an attempt to control wild oats on the experimental site. As was the case on the Elstow soil treatments 0, 6 and 15 were used to collect data on dry matter production and nitrogen uptake at four stages of crop growth. In comparing the data for treatment 15 it should be noted that the percent ATC coat on the urea for the Elstow soil was 1.0% and for the Melfort soil 0.3%.

EXPERIMENTAL RESULTS

I. Bradwell soil - Summerfallowed plot

The average NO_3^--N and NH_4^+-N content expressed in ug N/g of soil for the various treatments, soil depths and sampling dates are shown in Table 4.

The examination of these results show no significant differences in the NO_3^- and NH_4^+ concentrations in the soil for the check, 1.0 kg ATC/ha and 4.0 kg ATC/ha treatments throughout the period of the experiment. It is concluded from these data that there was essentially no effect of the nitrification inhibitor, at the rates used, on the oxidation of soil ammonium to nitrate by the nitrifying organisms in the soil.

Significant differences in the NO_3^- and NH_4^+ levels, where observed, however, for the 200 kg N/ha urea, 200 kg N/ha 0.5% ATC coated urea and 200 kg N/ha 2.0% ATC coated urea treatments. At the first sampling date (May 22) two weeks after application NO_3^- levels were still relatively low and NH_4^+ levels were relatively high indicating that hydrolysis of urea had taken place but the NH_4^+ had not yet been nitrified. As the season progressed, NO_3^- levels increased and were in the order of urea $>$ 0.5% ATC $>$ 2.0% ATC. Ammonium levels on the other hand were found to decrease in the reverse order of 2.0% ATC $>$ 0.5% ATC $\geq$ urea.

The extent of the inhibition of nitrification in relation to time and the percentage ATC coat can be more easily seen by converting the NO_3^- and NH_4^+ levels found in the soil from the fertilizer application to a kg/ha 60 cm basis. This was done by subtracting the NO_3^- and NH_4^+ levels in the check treatment from those measured in the urea and urea plus ATC

Table 4. Average NO_3^--N and NH_4^+-N content by treatment of soil samples from four soil depths for ten sampling dates (μg N/g). Data is average of four replicates. Goodale summerfallow site.

Table 4.1. Check Treatment

Sampling Date	Sample Depth (cm) 0-7		7-15		15-30		30-60	
	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+
May 13*	2.9	3.0	2.7	2.8	2.6	3.5	1.0	3.5
May 22	2.8	4.8	2.2	4.4	2.8	3.9	1.0	4.0
June 10	1.8	2.4	2.0	2.0	3.2	1.6	1.4	1.9
June 24	3.5	2.8	3.7	2.9	3.3	2.8	1.7	2.6
July 8	4.4	3.1	4.8	2.6	2.9	2.0	2.2	2.5
July 22	4.6	2.9	4.6	3.4	4.2	3.0	2.1	2.5
August 5	6.0	3.4	4.7	3.1	4.0	3.3	2.7	2.8
August 19	8.6	4.0	5.8	2.5	4.0	3.0	2.9	2.5
September 2	9.3	3.9	5.2	2.6	3.4	2.6	2.4	2.8
September 16	7.5	2.4	4.6	3.0	3.7	2.9	2.3	2.8

Table 4.2. 200 kg N/ha 0.5% ATC Coated Urea

Sampling Date	Sample Depth (cm) 0-7		7-15		15-30		30-60	
	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+
May 13*	2.9	3.0	2.7	2.8	2.6	3.5	1.0	3.5
May 22	6.3	53.8	5.4	50.8	3.3	6.5	1.0	5.0
June 10	19.2	39.0	15.4	8.1	7.9	1.9	1.7	1.8
June 24	41.5	49.3	26.9	18.3	10.5	4.4	3.1	3.8
July 8	52.1	12.3	35.6	6.6	15.2	3.0	4.3	2.9
July 22	28.1	6.3	38.0	9.8	23.4	3.3	6.1	3.6
August 5	38.2	3.8	52.0	3.0	21.4	3.1	8.4	3.5
August 19	51.0	4.0	41.3	3.0	17.3	2.8	9.2	3.3
September 2	50.0	4.8	35.5	4.1	15.0	2.6	5.6	2.8
September 16	55.3	2.9	29.0	2.4	18.3	2.5	4.1	2.8

Table 4.3. 200 kg N/ha 2.0% ATC Coated Urea

Sampling Date	Sample Depth (cm) 0-7 NO_3^-	0-7 NH_4^+	7-15 NO_3^-	7-15 NH_4^+	15-30 NO_3^-	15-30 NH_4^+	30-60 NO_3^-	30-60 NH_4^+
May 13*	2.9	3.0	2.7	2.8	2.6	3.5	1.0	3.5
May 22	3.7	81.8	4.6	17.1	2.6	5.6	0.6	4.9
June 10	6.8	93.6	6.8	25.8	5.9	4.6	1.7	2.8
June 24	16.5	58.5	10.8	13.8	6.8	4.5	2.0	3.3
July 8	27.3	54.3	18.9	29.6	7.5	5.3	3.3	4.3
July 22	41.7	25.4	29.5	23.0	12.7	3.9	5.6	3.3
August 5	41.8	24.8	30.0	15.3	17.9	9.0	9.4	5.7
August 19	38.1	25.1	36.0	13.8	13.1	3.5	7.9	5.8
September 2	61.5	36.8	37.3	14.0	11.9	3.4	7.9	5.6
September 16	59.0	11.6	21.1	4.5	11.5	3.0	4.2	3.0

Table 4.4. 200 Kg N/ha Urea

Sampling Date	Sample Depth (cm) 0-7 NO_3^-	0-7 NH_4^+	7-15 NO_3^-	7-15 NH_4^+	15-30 NO_3^-	15-30 NH_4^+	30-60 NO_3^-	30-60 NH_4^+
May 13*	2.9	3.0	2.7	2.8	2.6	3.5	1.0	3.5
May 22	6.9	93.8	11.2	30.5	3.8	9.8	0.9	4.1
June 10	48.3	11.0	47.0	20.1	18.5	2.8	3.3	1.9
June 24	45.9	8.0	43.6	4.5	20.0	2.9	3.1	2.6
July 8	44.2	5.3	51.2	3.9	27.5	2.9	5.4	2.6
July 22	18.6	2.9	45.4	3.3	31.6	3.6	11.9	2.9
August 5	30.2	4.4	48.5	3.5	32.2	3.1	16.1	3.9
August 19	57.3	5.3	55.3	2.5	39.3	2.8	10.3	3.1
September 2	44.3	4.4	43.0	2.5	26.7	2.5	7.1	3.1
September 16	63.0	2.6	45.8	2.6	28.3	3.4	7.4	2.6

Table 4.5. 1.0 kg ATC/ha

Sampling Date	Sample Depth (cm) 0-7 NO_3^-	0-7 NH_4^+	7-15 NO_3^-	7-15 NH_4^+	15-30 NO_3^-	15-30 NH_4^+	30-60 NO_3^-	30-60 NH_4^+
May 13*	2.9	3.0	2.7	2.8	2.6	3.5	1.0	3.5
May 22	2.4	4.8	2.9	4.6	2.5	4.1	0.8	4.1
June 10	2.2	2.6	2.0	2.5	3.0	2.6	1.5	2.0
June 24	4.6	3.9	3.2	2.9	3.7	2.6	2.4	2.3
July 8	5.5	3.0	5.2	2.8	3.6	2.6	1.9	2.6
July 22	4.9	1.9	4.3	2.9	3.7	3.1	2.3	2.5
August 5	6.5	3.1	4.7	2.6	4.3	2.6	4.4	3.3
August 19	9.9	3.4	7.4	3.0	4.8	2.9	3.4	3.1
September 2	9.6	4.0	7.0	2.5	3.8	2.9	2.7	3.1
September 16	9.8	2.8	5.1	2.3	4.1	2.5	2.6	3.0

Table 4.6. 4.0 kg ATC/ha

Sampling Date	Samplg Depth (cm) 0-7 NO_3^-	0-7 NH_4^+	7-15 NO_3^-	7-15 NH_4^+	15-30 NO_3^-	15-30 NH_4^+	30-60 NO_3^-	30-60 NH_4^+
May 13*	2.9	3.0	2.7	2.8	2.6	3.5	1.0	3.5
May 22	2.5	3.9	3.0	4.6	1.8	3.6	0.6	3.9
June 10	1.6	3.5	2.2	3.5	2.5	2.8	1.0	2.1
June 24	4.2	2.6	3.5	2.4	3.0	2.1	1.6	2.4
July 8	5.6	3.0	5.1	3.1	3.7	2.5	2.9	2.5
July 22	5.7	2.1	4.2	3.3	4.0	2.3	2.1	2.6
August 5	8.3	3.4	6.4	3.8	5.6	2.8	6.2	4.4
August 19	11.4	4.0	7.0	3.3	4.8	3.0	3.4	3.3
September 2	11.8	6.6	7.2	4.4	4.2	4.8	2.7	3.1
September 16	8.4	2.0	4.2	2.5	3.4	2.3	2.3	3.0

* Levels of NO_3^--N and NH_4^+-N prior to urea and ATC application.

treatments.

Figures 1 and 2 show respectively the time course of NH_4^+-N depletion and NO_3^--N formation for the urea, 0.5% ATC and 2.0% ATC coated urea treatments. Figure 1 indicates that the NH_4^+-N formed from 200 kg N/ha applied as urea was virtually depleted six weeks after application. When the same application was coated with 0.5% ATC NH_4^+-N recovered in the soil was somewhat higher and a portion was retained for approximately 10 weeks. When a 2.0% ATC coat was used a significant portion remained in the NH_4^+ form for a 16 week period. Figure 2 shows the rate of NO_3^--N formation for the same treatments. For the urea treatment the NO_3^- levels rose rapidly during the 2 to 4 week period but surprisingly did not peak until the 14th week. The effect of the ATC coat was to delay the formation of NO_3^--N by the soil organisms with the 2.0% ATC being more effective than the 0.5% ATC material. During the 18 week experimental period the amount of NO_3^--N recovered in the 0-60 cm profile for the ATC coated urea was always below that for the urea treatment.

Figure 3 shows the percent recovery of the applied fertilizer material as measured by difference in the 0-60 cm soil profile. It is interesting to note that the percentage recovery of 200 kg N/ha treatment (NH_4^+ + NO_3^- in fertilizer treatment - NH_4^+ + NO_3^- in check treatment) is greater for urea than for the ATC coated urea. Since the formation of NO_3^--N was not delayed for ordinary urea one might expect that the chance of leaching NO_3^- below the 60 cm depth would be the greatest on this treatment. However, this does not appear to be the case. The possible explanations for the lower recovery of NH_4^+ and NO_3^- from the ATC coated materials may be either due to increased volatile losses or the fixation of the ammonium formed from the urea. Since nitrification inhibitors have little effect on urea hydrolysis, their effect is to retard the nitrification of the ammonium formed and in this manner may increase the gaseous loss of urea nitrogen as ammonia.

II. Wheat yields and nitrogen uptake from plots treated with urea and ATC coated urea

Urea fertilizer and urea coated with two levels of ATC was applied at four rates on an irrigated Elstow soil and a Melfort soil. Neepawa wheat was the test crop used in these experiments. The experimental details are given in Tables 2 and 3.

Total above ground dry matter production was determined on three treatments at each site at various stages of growth. On the Elstow soil, samples were obtained at tillering, flag leaf, heading, soft dough and maturity. On the Melfort soil, plant samples were taken at the flag leaf, heading, soft dough and mature growth stages. In addition to dry matter production the percent nitrogen in the plant tissue was determined and the

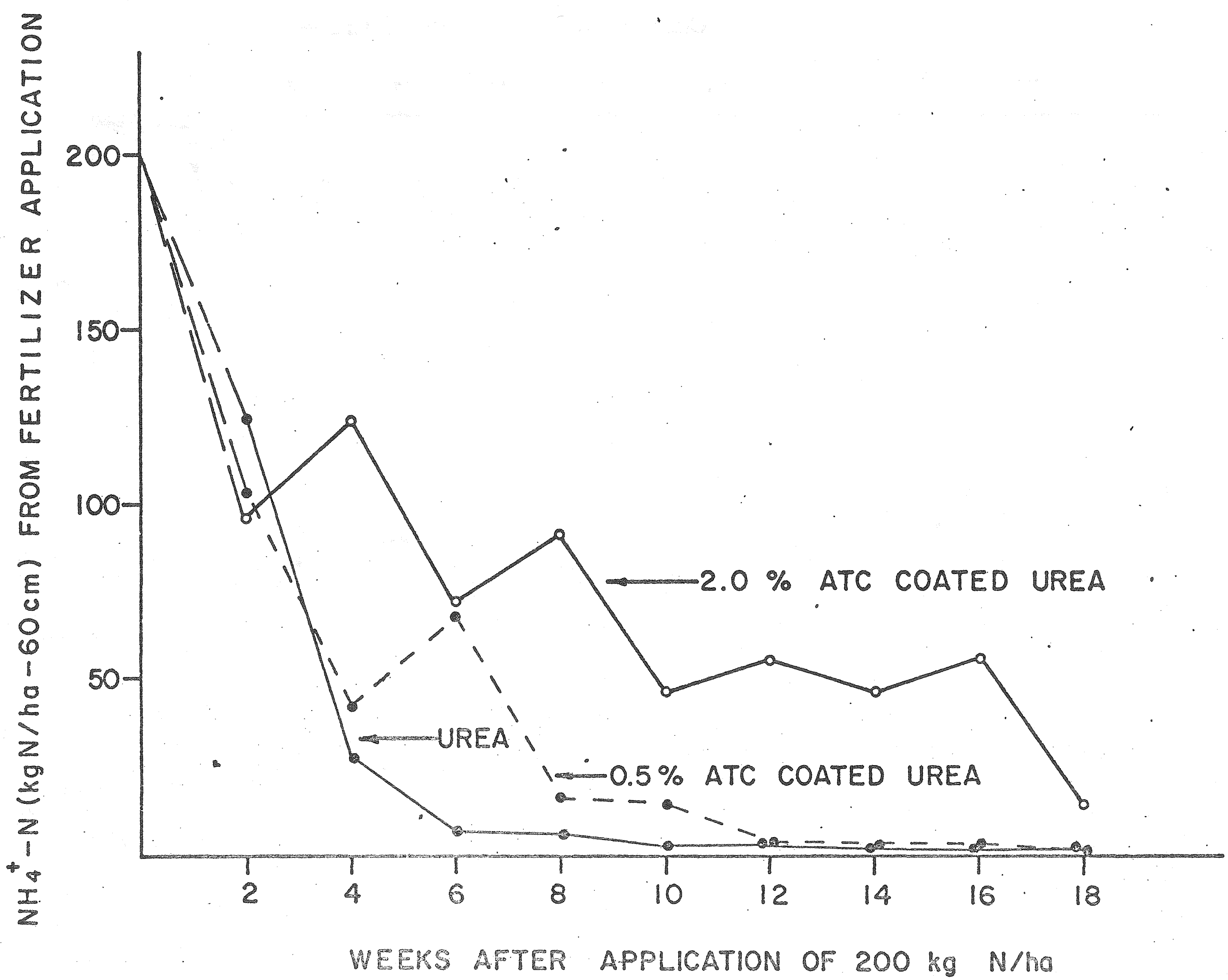

Figure 1. NH_4^+-N levels (kg/ha - 60 cm) above the check treatment at two week intervals for the urea and ATC coated urea treatments on the Goodale plot (Bradwell soil).

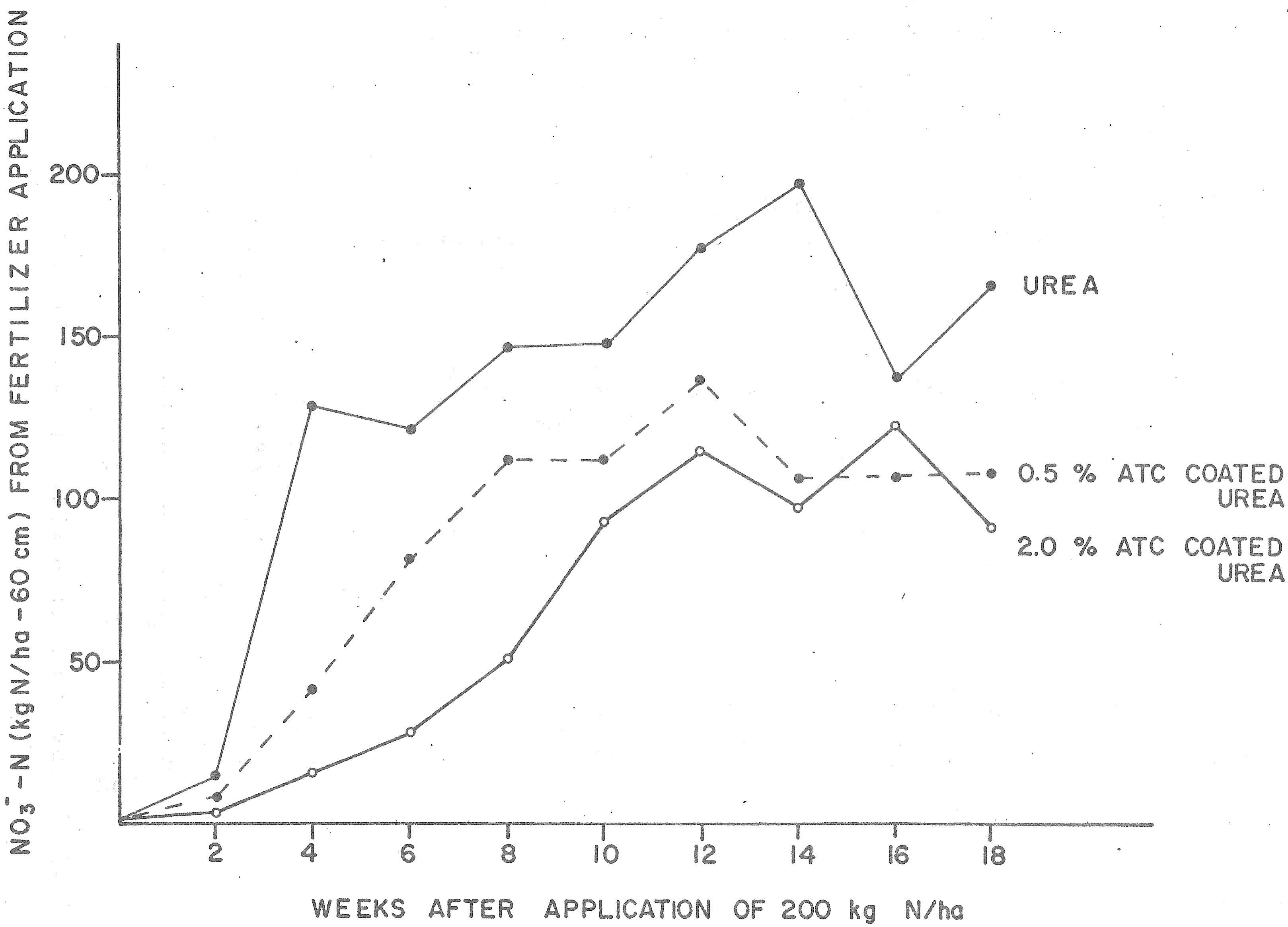

Figure 2. NO_3^--N levels (kg/ha - 60 cm) above the check treatment at two week intervals for the urea and ATC coated urea treatments on the Goodale plot (Bradwell soil).

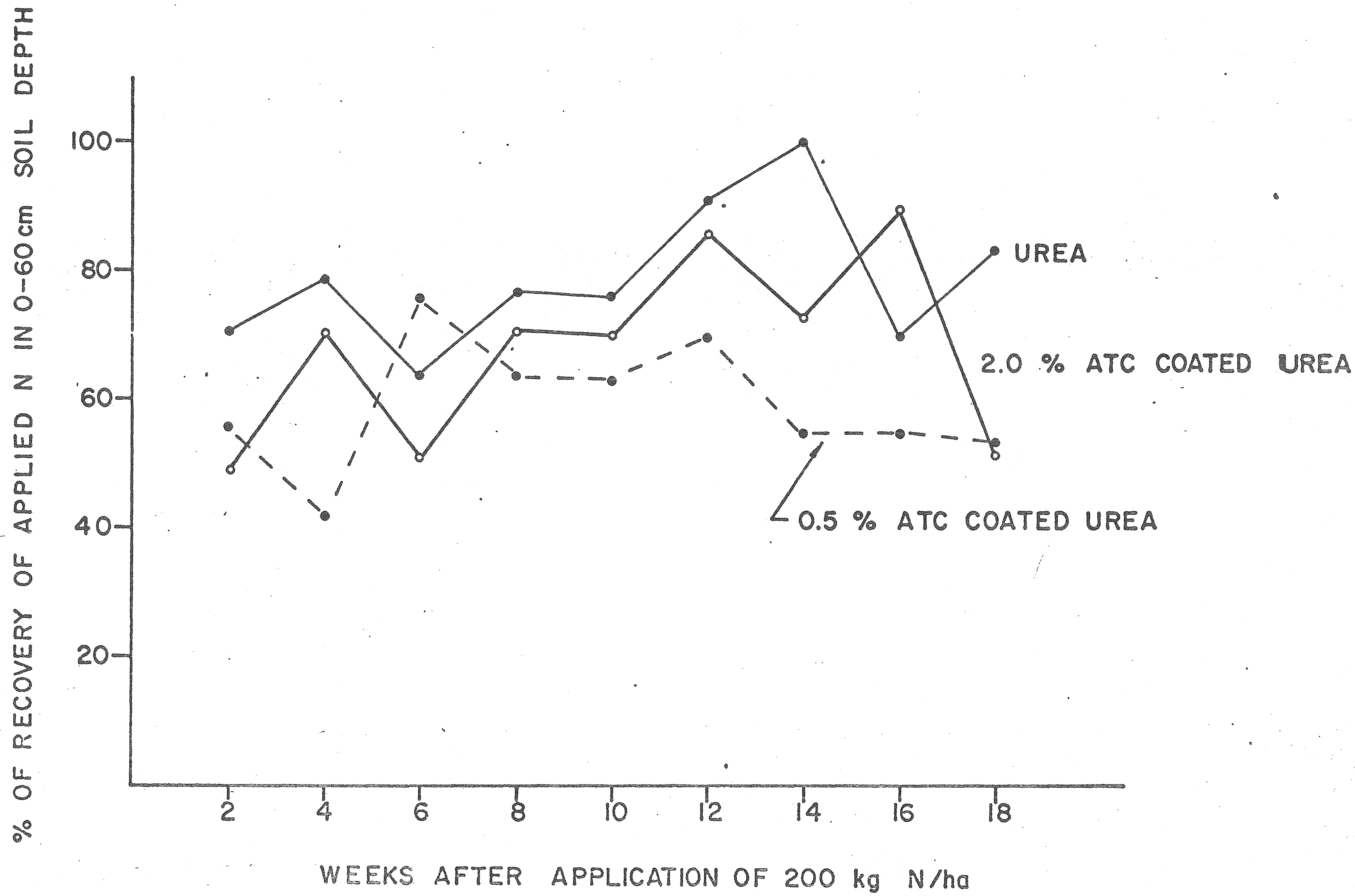

Figure 3. Percentage recovery of applied N in the 0-60 cm soil depth at two week intervals for the urea and ATC coated urea treatments on the Goodale plot (Bradwell soil).

nitrogen uptake in kg/ha calculated. The data obtained for the two sites are shown in Tables 5 and 6.

At both sites there was a strong response to applied nitrogen fertilizer for both urea and urea coated with ATC. For both treatments, dry matter yields were significantly greater than for the zero nitrogen control. No significant differences in dry matter production between the urea and the urea coated with ATC were found for any of the sampling dates at either location.

The nitrogen content of the above ground plant material expressed on a percent N basis decreased throughout the growing season. Where N was applied the nitrogen content of the plant tissue was significantly greater than where no nitrogen was applied. However, there was no significant difference in the nitrogen content of plant tissue between the urea and the urea coated with 1.0% ATC on the irrigated Elstow soil at any of the growth stages. The nitrogen content of the samples from the Melfort site was significantly greater for the urea coated with 0.3% ATC than for ordinary urea at the heading and soft dough growth stages.

Total nitrogen uptake increased throughout the growing season reaching a maximum at the soft dough stage of growth at both sites. The nitrogen uptake for the control treatments was much less when compared to the treatments receiving nitrogen. However, there was no difference in total nitrogen uptake between the urea and ATC coated urea treatments.

The yield of grain and straw on both the Elstow and Melfort soils increased with increasing rates of fertilizer nitrogen application (Tables 7 and 8). However, there were no significant differences between the yields of either grain on straw for urea or the urea coated with ATC at any one rate of nitrogen application. At both sites, grain protein and straw nitrogen content increased with increasing rates of N application. On the irrigated Elstow soil the grain protein content at the 200 kg N/ha rate was significantly higher for the ATC coated materials than for ordinary urea. However, no other general trends were observed in the data which indicate greater nitrogen uptake by wheat from either urea or urea coated with ATC.

Table 5. The effect of urea and urea coated with ATC on dry matter production, N content, N uptake and P content at five growth stages throughout the growing season for the irrigated wheat plot (Elstow soil).

Sampling* Date	Growth Stage	Treatment**	Total wt. (kg/ha)	% N	N uptake (kg/ha)	% P
June 1(18)	Tillering	Control	118	4.79	5.65	0.464
		Urea	142	4.91	6.97	0.472
		Urea + 1.0% ATC	172	4.90	8.43	0.434
		L.S.D.	N.S.	0.26	--	N.S.
June 18(35)	Flagleaf	Control	640	3.43	21.95	0.402
		Urea	978	4.74	46.36	0.481
		Urea + 1.0% ATC	1015	4.75	48.21	0.502
		L.S.D.	337	0.18	--	0.02
July 5(52)	Heading	Control	1527	1.65	25.20	0.261
		Urea	4178	2.68	111.97	0.296
		Urea + 1.0% ATC	3994	2.84	113.43	0.305
		L.S.D.	477	0.17	--	0.04
July 22(69)	Soft dough	Control	3433	1.05	36.05	0.228
		Urea	6960	2.20	153.12	0.248
		Urea + 1.0% ATC	6883	1.88	129.40	0.216
		L.S.D.	654	0.19	--	0.03
Aug. 18(96)	Maturity	Control	4152	0.64	26.57	0.199
		Urea	9714	1.01	98.11	0.150
		Urea + 1.0% ATC	10954	1.00	109.54	0.128
		L.S.D.	942	0.11	--	0.02

*Numbers in parenthesis represents number of days after seeding.

**Urea and urea + 1.0% ATC applied at a rate of 200 kg N/ha.

Table 6. The effect of urea and urea coated with ATC on dry matter production, N content, N uptake and P content at four growth stages throughout the growing season for the dryland wheat plot (Melfort site).

Sampling* Date	Growth Stage	Treatment**	Total wt. (kg/ha)	% N	N uptake (kg/ha)	% P
June 30(42)	Flagleaf	Control	1390	2.21	30.72	0.308
		Urea	1467	4.31	63.23	0.424
		Urea + 0.3% ATC	1247	4.51	56.24	0.407
		L.S.D.	N.S.	0.30	--	0.02
July 16(58)	Heading	Control	2440	1.46	35.62	0.265
		Urea	3527	3.03	106.87	0.343
		Urea + 0.3% ATC	3603	3.22	116.02	0.367
		L.S.D.	514	0.08	--	0.03
Aug. 13(86)	Soft dough	Control	4362	0.79	34.46	0.256
		Urea	6879	1.33	91.49	0.158
		Urea + 0.3% ATC	6197	1.63	101.01	0.177
		L.S.D.	1431	0.21	--	0.02
Sept. 1(105)	Maturity	Control	5111	0.70	35.78	0.185
		Urea	8186	0.94	76.95	0.126
		Urea + 0.3% ATC	7684	1.06	81.45	0.133
		L.S.D.	1621	0.21	--	N.S.

*Numbers in parentheses represents number of days after seeding.

**Urea and urea + 0.3% ATC applied at a rate of 200 kg N/ha.

Table 7. The effect of urea and urea coated with ATC on the yield, N content, P content, and N uptake of irrigated wheat for the Outlook plot (Elstow soil).

Treatment (kg N/ha)	Yield (kg/ha)		Grain* Protein (%)	Grain†		Straw†		N uptake (kg/ha)		
	Grain	Straw		N (%)	P (%)	N (%)	P (%)	Grain	Straw	Total
0	2090	3086	10.41	2.11	0.50	0.20	0.05	44.1	6.2	50.3
25 Urea	2843	3856	10.87	2.21	0.48	0.23	0.03	62.8	8.9	71.7
50 Urea	3067	4276	11.27	2.29	0.48	0.29	0.04	70.2	12.4	82.6
100 Urea	3729	5229	12.83	2.60	0.47	0.32	0.03	97.0	16.7	113.7
200 Urea	3995	5819	13.58	2.76	0.46	0.41	0.03	110.3	23.9	134.2
25 Urea with 0.3% ATC	2761	4026	10.91	2.21	0.50	0.23	0.05	61.0	9.3	70.3
50 Urea with 0.3% ATC	3131	4758	10.80	2.19	0.49	0.26	0.05	68.6	12.4	81.0
100 Urea with 0.3% ATC	3645	5063	12.43	2.52	0.48	0.32	0.03	91.9	16.2	108.1
200 Urea with 0.3% ATC	3998	5670	14.18	2.88	0.46	0.44	0.03	115.1	24.9	140.0
25 Urea with 1.0% ATC	2360	3441	10.34	2.10	0.50	0.23	0.04	49.6	7.9	57.5
50 Urea with 1.0% ATC	3077	4248	11.12	2.26	0.49	0.23	0.03	69.5	9.8	79.3
100 Urea with 1.0% ATC	3792	5525	12.27	2.49	0.48	0.29	0.01	94.4	16.0	110.4
200 Urea with 1.0% ATC	4043	5507	15.00	3.04	0.48	0.43	0.03	122.9	23.7	146.6
L.S.D.	735	1043	0.17	0.12	0.04	--	--	--	--	--

*Grain protein based on % N at 13.5% moisture x 5.7.
†Straw and grain % N and % P on oven-dry basis.

Table 8. The effect of urea and urea coated with ATC on the yield, N content, P content, and N uptake of wheat for the Melfort plot (Melfort soil).

Treatment (kg N/ha)	Yield (kg/ha)		Grain* Protein (%)	Grain†		Straw†		N uptake (kg/ha)		
	Grain	Straw		N (%)	P (%)	N (%)	P (%)	Grain	Straw	Total
0	1026	2146	12.97	2.63	0.37	0.41	0.12	27.0	8.8	35.8
25 Urea	1311	3256	11.22	2.28	0.36	0.35	0.09	33.4	8.5	41.9
50 Urea	1788	3995	12.56	2.55	0.37	0.26	0.07	40.8	14.0	54.8
100 Urea	1941	4499	12.31	2.50	0.36	0.41	0.08	48.5	18.4	66.9
200 Urea	2686	5859	14.70	2.98	0.30	0.53	0.05	80.0	31.1	111.1
25 Urea with 0.3% ATC	1408	3465	12.09	2.45	0.38	0.35	0.09	34.5	12.1	46.6
50 Urea with 0.3% ATC	1659	3986	13.01	2.64	0.38	0.41	0.10	43.8	16.3	60.1
100 Urea with 0.3% ATC	1791	4403	13.58	2.76	0.36	0.58	0.08	49.4	25.5	73.9
200 Urea with 0.3% ATC	2686	5866	15.08	3.06	0.32	0.64	0.05	82.2	37.5	119.7
25 Urea with 1.0% ATC	1591	3563	12.04	2.44	0.49	0.38	0.09	38.8	13.5	52.3
50 Urea with 1.0% ATC	1564	4252	11.77	2.39	0.47	0.44	0.11	37.4	18.7	56.1
100 Urea with 1.0% ATC	2123	4853	11.98	2.43	0.47	0.35	0.05	51.6	17.0	68.6
200 Urea with 1.0% ATC	2157	5565	13.98	2.84	0.42	0.79	0.07	61.3	44.0	105.3
L.S.D.	686	1247	0.69	0.14	0.04	--	--	--	--	--

*Grain protein based on % N at 13.5% moisture x 5.7.

†Straw and grain % N and % P on oven-dry basis.