



**NITROGEN LOSS FROM
SURFACE-APPLIED UREA**

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Introduction

Fertilization practices in the British Columbia forest industry are still in the early stages of development and little, if any, meaningful information has been obtained (9). Lee (8), in his survey of literature on forest fertilization in British Columbia, reported that of the studies currently in progress, only four are concerned with growth response in established stands.

In addition to the limited number of current fertilization studies, there is little pertinent information available regarding the nutrient requirements of established stands, both as to kinds and quantities. Assuming that nitrogen is the nutrient element required in greatest amount and frequency, the lack of sufficient research data regarding the nitrogen-carrier, most efficient as a nitrogen source and which will give maximum economic returns, is another urgent problem requiring attention.

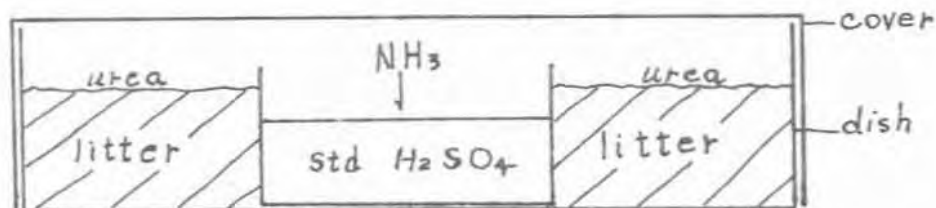
In the British Columbia forest industry, urea is the most frequently used form of nitrogen by virtue of its high nitrogen content (46%). In other parts of the world, notably Sweden, the popularity of urea as a nitrogen source has recently declined, while that of ammonium nitrate and sulfate has increased (7). The chemical and physical nature of both nitrogen-carrier and soil material will, in large measure, control the degree to which the reaction between the two will proceed. Accordingly, as Holmen (7) suggested, on certain

soil materials ammonium nitrate was superior to urea as a nitrogen source. The findings of Acquaye and Cunningham (1) and those of Simpson (13) confirm Holmen's view. These investigators suggested that additional factors, such as soil and air temperatures and humidities, are also important.

This report describes the results obtained from an experiment in which urea, at 400 N lb/acre was applied to the surface of litter under a variety of environmental conditions. Recommendations are made regarding the use of urea as a nitrogen source under field conditions and for industrial applications.

Methods

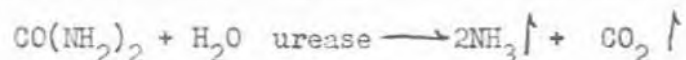
The loss of nitrogen, as volatile constituents, from surface applications of urea under the several sets of conditions, as shown in Table 1, were measured at convenient intervals and recorded (Table 2). Nitrogen at 400 lb/acre was applied as urea to the surface of 10 g of <2 mm litter which had been adjusted with reference to moisture and pH. These materials were placed in petri dishes and allowed to react in the presence of an accurate volume of standard sulfuric acid (0.1N). Diagrammatically the system was as follows:



The chemical analyses undertaken included the estimation of ammonia loss by volatilization by back-titration with standard base, residual urea by the method of Watt and Chrisp (17), nitrate-nitrogen by the Orion specific ion pH meter and pH by the glass electrode using a 2:1 water-soil suspension. Residual urea and nitrate-nitrogen estimations were made on a cleared-water extract of the urea-treated litter upon completion of the experiment.

Results and Discussion

Bergmeyer (2) has recorded the degradation of urea applied in the presence of the enzyme urease. Since urease is ubiquitous in nature (3), urea applied to the soil surface is likewise attacked and hydrolyzed enzymatically according to the following equation:

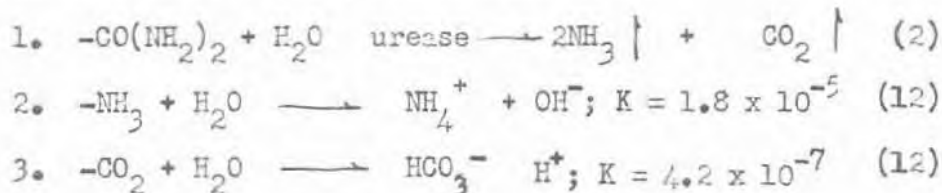


Under optimum conditions, the reaction proceeds rapidly and completely to the right since both products are volatile. The principal objective of this study was to determine the extent that external factors, such as moisture, pH and temperature, played in the loss of nitrogen as volatile ammonia (NH_3).

In no case in which air-dry (<10% moisture) litter was used, regardless of treatment adjustment or of pH, was there any loss of nitrogen as ammonia during the entire experiment, indicating that moisture above the air-dry level is necessary to initiate the enzymatic degradation of the urea molecule. Samples adjusted to 150 and 300 per cent moisture (approximately one-half and full saturation) and to pH 4

and 6, but which did not receive the urea treatment, showed a slight volatilization loss. Samples of comparable moisture levels but with different pH values, showed slightly higher but insignificant losses from the material adjusted at the higher pH; losses at 55°F were only very slightly higher than those at 40°F.

As expected, samples adjusted with reference to moisture and pH and treated with urea exhibited considerable ureolysis activity. Losses recorded (Table 2) have been adjusted to take into account those normally occurring as a result of the decomposition of untreated litter. Hence, values reflect percentage losses of applied urea. The data (Table 2 and Fig. 1) show some interesting features both as to total loss and the rate of loss of nitrogen for the several conditions under which the experiment was carried out. Clearly, both moisture level and pH played an important role in the loss of applied nitrogen under both temperature conditions. At a given temperature and moisture level, those samples adjusted to the higher pH value have a more rapid rate of loss as well as a greater total loss of nitrogen. This is particularly true in the initial and earlier phases of the study. By the termination of the investigation, pH values had increased to 8 or above, regardless of the initial value. That such may be expected is obvious from the following set of equations:



The reaction products of eq 1, ammonia and carbon dioxide, are soluble in water and react with it, as shown in eqs 2 and 3. It is obvious, however, from the ionization constants (K) given that the NH_3 - water reaction is considerably stronger than that of CO_2 - water. As a result, much more hydroxyl ion (OH^-) is produced than hydrogen ion (H^+), with the net result that pH is markedly increased.

At a given pH and temperature, the effect of increasing the moisture from 150 to 300 per cent was to delay the loss of nitrogen. Maximum loss of nitrogen in samples with moisture adjusted to 300 per cent or saturation occurred approximately two weeks later than that for samples adjusted to 150 per cent or half-saturation (Fig. 1). Generally, losses were higher during the second half of the experiment from those samples having 300 per cent moisture adjustment (Table 2).

The low temperature (40°F) tended to delay nitrogen losses somewhat at both pH and moisture levels. Total nitrogen losses were usually greatest from samples kept at 55°F (Table 2).

These observations regarding the influence of pH, moisture content and temperature on both the rate of loss and total loss of nitrogen have been confirmed by others (5, 10, 15, 16). There are conflicting views, however, regarding the roles played by external factors on the conversion of urea in soils (6, 11).

Upon completion of the experiment, unconverted urea and nitrate-nitrogen were not detected in any of the urea-treated samples which had been adjusted with reference to pH and moisture content. This suggests, as others have found, that conversion of urea in the soil

is rapid and that nitrification is inhibited in the presence of toxic amounts of ammonia and extremely high pH values (3, 4).

Conclusions and Recommendations

Losses of nitrogen from applied urea by volatilization occurred and the rate of total loss were influenced by the initial pH, moisture content and temperature. Under the experimental conditions, as much as 21 per cent of the nitrogen applied was lost by volatilization.

It has been suggested that the biochemical hydrolysis of urea is considerably more rapid and of much more significance than the chemical hydrolysis (3) and, as a result, the danger of nitrogen loss, as ammonia, from urea applications is always high. Under field conditions there is the additional danger of losses through fixation and leaching. These results and those of others (14) suggest that nitrogen losses from urea under field applications can be minimized if the fertilization operation is carried out in the cooler and wetter portions of the year.

Table 1. Environmental Conditions of Experiment

N lb/acre	Moisture %	pH	Temperature (°F) of Study	
0	air-dry	6	55	40
0	"	4	"	"
400	"	6	"	"
400	"	4	"	"
0	150	6	55	40
0	"	4	"	"
400	"	6	"	"
400	"	4	"	"
0	300	6	55	40
0	"	4	"	"
400	"	6	"	"
400	"	4	"	"

Table 2. Loss of added* N by volatilization under the several sets of conditions described

Treatment			N-loss by volatilization-per cent (55°F)											total loss
N-lb.	Moist.-%	pH	time in days											
			4	7	10	13	18	22	27	32	42	54		
400	150	6	1.77	4.49	3.75	4.11	1.40	1.63	1.60	0.47	0.86	1.10	21.18	
400	150	4	0.55	2.09	1.58	1.69	0.60	0.76	0.78	0.26	0.50	0.68	9.49	
400	300	6	0.13	0.31	-	-	3.26	3.74	4.41	1.17	2.17	2.46	17.65	
400	300	4	0.00	0.10	-	-	3.18	2.43	3.56	1.00	2.06	2.24	14.57	

Treatment			N-loss by volatilization-per cent (55°F) ⁴⁰											total loss		
N-lb.	Moist.-%	pH	time in days													
			6	8	10	11	13	20	22	27	28	29	34		43	57
400	150	6	1.06	2.86	1.77	-	2.70	1.80	1.63	-	1.54	-	0.48	0.92	1.23	15.99
400	150	4	0.13	1.66	1.43	-	2.25	1.41	1.43	-	1.45	-	0.43	0.73	1.06	11.98
400	300	6	0.13	-	-	1.70	-	3.28	0.94	2.50	-	2.20	1.04	2.04	2.76	16.59
400	300	4	0.00	-	-	1.20	-	3.22	0.51	1.48	-	1.30	0.64	1.20	1.86	11.41

* N - was added at the rate of 400 lb. as urea to the litter surface.

Fig. 1 Nitrogen loss, with time, from surface - applied urea (55° F.)

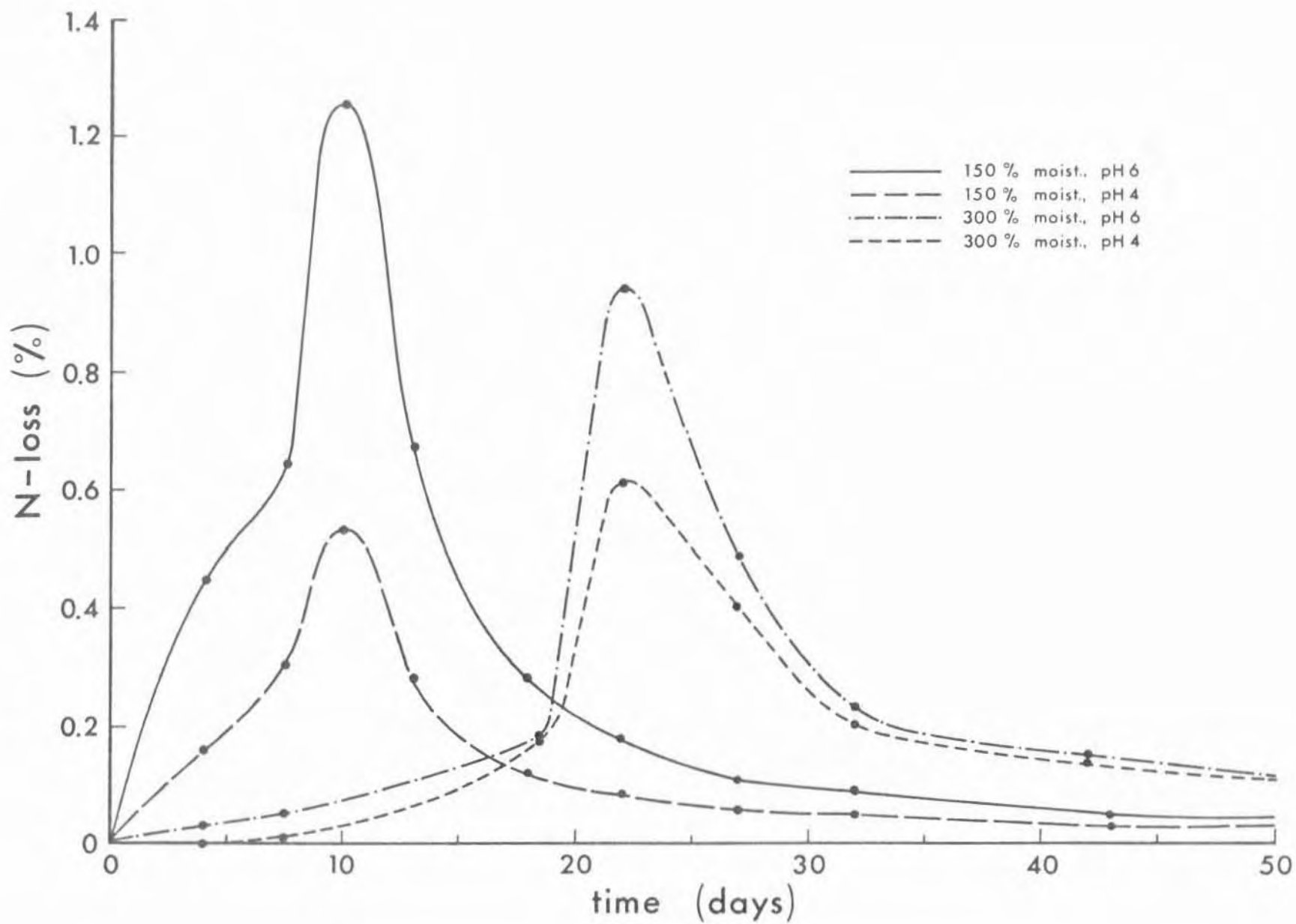
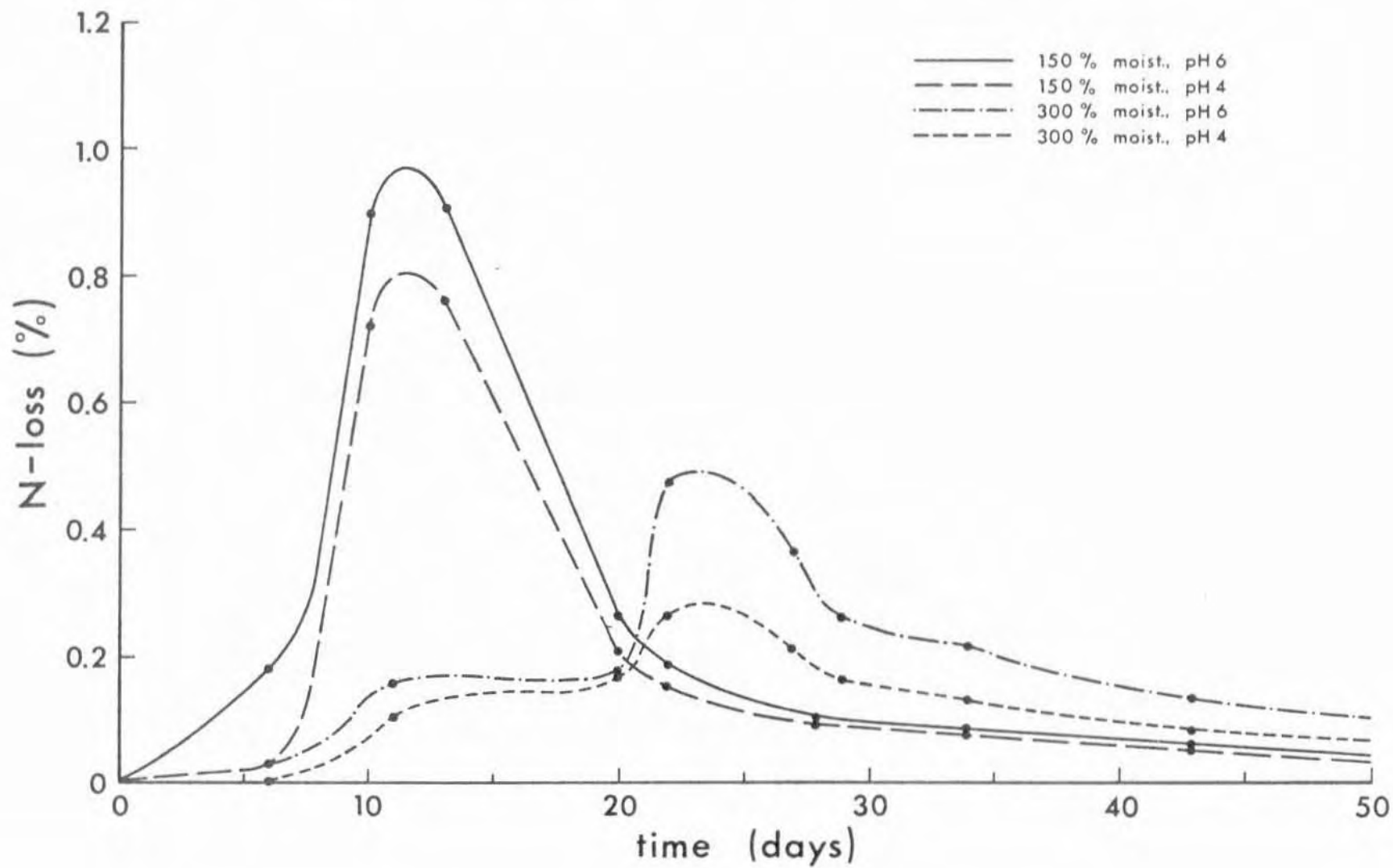


Fig. 1 Nitrogen loss, with time, from surface - applied urea (40° F.)



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