

**SOME EFFECTS OF UREA FERTILIZATION  
ON SOIL CHARACTERISTICS AND TISSUE  
MINERAL CONTENT IN OVERSTOCKED  
WESTERN HEMLOCK STANDS**


**by**  
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Introduction

Overstocked stands of western hemlock are numerous on Vancouver Island. That stand density influences both the individual tree performance and harvest of merchantable timber is well known. In the past, operators have used spacing techniques such as hand-thinning and girdling to maintain an acceptable stand density throughout the productive growth period. However, these practices are costly and time-consuming even under the most favorable conditions. The careful use of fertilizer on overstocked stands could probably hasten the natural expression of dominance in some trees and the suppression in others.

To determine the feasibility of controlling stand density at a desired level by fertilization, several rates of nitrogen were used in a study initiated in three dense hemlock stands on Vancouver Island.

This report discusses the effects of the various rates of nitrogen on the N, P and K levels of twig and needle tissues and on the soil nitrogen content and soil pH values. In addition, it records the influence of urea applications on other soil characteristics.

Description of Study Area

The soils of the three study areas, i.e., Jeune Landing, Woss Camp and Port Renfrew are brunisols. However, that of Jeune Landing was altered by the removal of the vegetative cover by a severe burn in 1951, with the result that the effects of elluviation are more apparent than

those normally expected. All stands were dense, between 10,000 and 16,000 stems per acre; from 20 to 30 feet high, and were from 12 to 17 years in age (1).

#### Methods

Treatments at 0, 50, 100, 200 and 400 pounds of N per acre as urea-nitrogen, in triplicate 1/50-acre plots were established in 1967 at Jeune Landing and Port Renfrew; the 400-pound treatment was eliminated at Woss Camp, otherwise the establishment of plots in this area was similar to the other two.

The nitrogen treatments were applied during the first two weeks of April, 1968, about six weeks before vegetative bud break so that the treatment effects would be recognizable in the current year tissues and growth. Fertilizer applications were made by hand by company personnel. To facilitate uniformity of application of the fertilizer, each plot was divided into four equal strips and one-quarter of the total amount of fertilizer per plot applied to each strip.

Before the application of fertilizer, in April, 1968, company personnel collected needle and twig tissues from appropriate trees within each plot which served as pre-treatment controls. The plots were re-sampled after fertilization the following November. Both spring and fall samples were sent to the Forest Research Laboratory, Victoria, for processing and analyses.

Soil samples from five locations within each plot and at four depths, (1-H), 0-2, 2-6 and 6-12 inches, were taken by Laboratory Personnel before fertilization, and the following July-August, 1968.

### Analytical Procedures

Analyses of total N, P and K were performed on samples of twig axes and needle tissues composed of current and one-year material from each treatment. Total nitrogen, in duplicate, was determined by the Kjeldahl digestion of the dried material, followed by alkaline distillation of the digestate. Total phosphorus and potassium determinations were made on ashed tissues by the molybdate and atomic absorption methods, respectively. Values have been expressed as percentages of tissue dry weight.

Analyses of the soil samples included: pH determination, using a saturation paste and a glass electrode; total nitrogen by the Kjeldahl procedure; exchangeable calcium, magnesium and potassium by ammonium chloride extraction, and cation exchange capacity by the distillation of adsorbed ammonium from the ammonium chloride extraction. Exchangeable ammonium of the litter surface was determined by direct distillation of the sample.

### Results and Discussion

#### Foliar and Twig Analyses

In the Jeune Landing samples, there was a consistent increase in the N-content in the fall twig and needle tissues from fertilized plots as contrasted to those from the controls; larger responses were associated with larger fertilizer applications. Port Renfrew samples showed a similar but somewhat less pronounced trend (Table 1).

At Woss Camp, only the tissues collected from control plots showed an increase in nitrogen for the fall, over that for the spring samples. Twig and needle tissues collected in the fall from the fertilized plots, regardless of rate, exhibited nitrogen levels considerably lower than those from the controls. The nitrogen levels of both tissues were more depressed

in samples from plots that received the least amount of fertilizer. Increasing the rate of fertilizer above 50 lb.N/acre increased the nitrogen level of tissues, but in no cases were the control values regained. This reaction to fertilization is difficult to explain. Possibly the nitrogen added was insufficient to meet the requirements of both the stand and the increased activity of the microbiological populations in the soil. The addition to the soil of a N-rich source probably disturbed the original C/N ratio and also the activity and numbers of the heterotrophic organisms, causing a temporary shortage of available nitrogen (6). Perhaps some of the reaction to fertilization observed for this area could be associated with stand age; the average age of the Woss Camp stand was from 3 to 5 years older than that for Port Renfrew and Jeune Landing.

Setting the per cent levels of N, P and K (Table 1) in the fall tissues from control plots at 100 and describing these nutrient levels in tissues from the fertilized plots in terms of this value, it is seen that the various rates of nitrogen added had an effect not only on the N uptake but also on the P and K uptake (Table 2). The addition of nitrogen to the Jeune Landing soil not only brought about an increase in the per cent level of nitrogen in the needle tissue, but also inhibited the uptake of phosphorus. Others (4, 5) have reported similar occurrences. As a result of fertilization, the increase in needle-nitrogen from the 50-pound treatment is 8 per cent, while that for the 400-pound treatment is 55 per cent. On the other hand, the phosphorus levels in the same tissues show decreases of 5 and 24 per cent, respectively. The influence of nitrogen additions on the potassium uptake in needle tissues is more variable than that exercised on the phosphorus uptake. However, as Tamm (5) has reported, as a result of the addition of

N there is a strong tendency for decreased uptakes of K. The overall trend in N, P and K changes with N fertilization holds also for the twig tissues from Jeune Landing.

The effects of fertilization on tissues from Port Renfrew were similar to those for the Jeune Landing samples with two exceptions, i.e., the magnitude of nitrogen and phosphorus changes in needle tissues was smaller; and the potassium uptake was not influenced.

The tissues from Woss Camp presented quite another picture. The addition of urea to the soil had a depressing effect upon the nitrogen levels. Phosphorus levels in these tissues were generally increased as a result of nitrogen additions. The lowest rate of fertilizer depressed to the greatest extent both nitrogen (38 and 33 per cent in needle and twig tissues) and potassium (12 and 11 per cent) uptakes, but enhanced to the greatest extent the phosphorus uptake. As the rate of fertilizer increased, the depressing effects on nitrogen and potassium uptake decreased; at the same time, the enhancement in phosphorus uptake also decreased.

#### Soil Analyses

The effect of urea treatments on soil was most pronounced on the litter surface and on the underlying adjacent mineral soil. The effects of fertilization were only slight in the deeper soil layers. As others (8) have reported those soil characteristics most influenced by urea applications were total nitrogen (Table 3), exchangeable ammonium (Table 4) and pH (Table 5). Water soluble and exchangeable Ca, Mg and K were influenced by the treatment and there is evidence of a downward movement of these cations (Table 4). Probably this was due to an increased mineralization of the litter surfaces. Some modification to the cation exchange capacity, especially to the surface in the samples from Jeune Landing and Port

Renfrew, also took place.

#### Total Soil Nitrogen

The effect of soil applications of urea on total soil nitrogen values of the litter surfaces of Jeune Landing and Port Renfrew was essentially the same (Table 3). Generally, an increase in the amount of urea applied increased the nitrogen percentage of the litter. In no case did the addition of urea increase the nitrogen level of the litter surface of Woss Camp soil. The effect of fertilization on the nitrogen contents of the mineral sub-soils was somewhat different. Only the Jeune Landing samples showed a general increase as a result of urea additions; samples from Port Renfrew and Woss Camp were either decreased or virtually unaffected. This differential response to nitrogen fertilization in the soils under study probably played a part in the differences reported in nitrogen levels for twig and needle tissues.

#### Exchangeable Ammonium and Exchange Capacity

The litter surfaces of soils showed a tendency to adsorb and retain nitrogen in the form of ammonium; the soil from Port Renfrew showed the strongest, and that from Woss Camp the least tendency to retain applied nitrogen (Table 4). Ammonium ion is produced during the enzymatic conversion and hydrolysis of urea in the soil (2, 7). Ammonium, being univalent and positively charged, becomes adsorbed on exchange sites in both organic and inorganic colloids and is retained in the soil medium. A noteworthy feature was the increased exchange capacities of the litter materials of Jeune Landing and Port Renfrew from the fertilized plots (Table 4). Only Jeune Landing showed an increase in exchange capacity in the mineral soils as a result of fertilization. These two soil characteristics, i.e., exchangeable

ammonium and exchange capacity, are related and help to explain the variations in total nitrogen levels reported above.

Due to the large amounts of free hydroxyl ion produced during the enzymatic hydrolysis of urea (8), alkaline hydrolysis of organic matter takes place. This hastens mineralization and humification of organic matter, resulting in a product (humus) having greatly increased activity and exposed surface area on which both adsorption and exchange reactions occur (Table 4) (6). The leaching of reaction products may explain the increased exchange capacities and nitrogen contents in the sub-soils of Jeune Landing; it is difficult to explain why a similar situation did not occur in the other two areas, particularly in Port Renfrew which also is a region of high precipitation (Table 6).

#### Soil pH

The most notable changes in soil pH as a result of urea fertilization occurred in the surface litter materials of Port Renfrew and Jeune Landing (Table 5). The pH of the surface litter of Port Renfrew increased almost 2 full pH-units and that of Jeune Landing 1 pH-unit by the 400 lb. treatment; the pH values of the surface litter from the fertilized plots from Woss Camp showed a decrease as compared with those of control plots. The pH values of mineral sub-soils from fertilized plots of all areas generally showed slight increases; the only exceptions were in the 0-2-inch depth from Woss Camp and the 6-12-inch depths from Jeune Landing.

The pH decreases noted in the Woss Camp soil, particularly those in the surface litter and mineral soil immediately beneath, are difficult to explain. This is especially so when it is known that one of the immediate end-products of enzymatic hydrolysis of urea is free hydroxyl ion (7), which

brings about a marked increase in pH. An explanation may be found in the precipitation and temperature patterns for the three areas (Table 6). Woss Camp received about one-half and one-third of the total precipitation of Jeune Landing and Port Renfrew, respectively, during the period between the application of fertilizer and the sampling of the soil. The total amounts of precipitation recorded are not measures of effective precipitation reaching the soil surface of the plots; this would be somewhat less. During the same period, Woss Camp experienced slightly higher temperatures than the other two area in the summer. The efficiency of conversion of urea is highly dependent upon both moisture content and temperature (9, 10).

#### Conclusions & Recommendations

Effects of nitrogen fertilization using urea were noted for the tissues and soils of the three study areas. The influence of soil applications of urea on twig and needle tissues from fertilized plots from Jeune Landing and Port Renfrew was generally similar, i.e., urea applications brought about an increase in nitrogen levels but a decrease in phosphorus uptake; potassium uptake was not consistently influenced by nitrogen applications. The results obtained in these areas indicate that fertilizer rates less than 200 lb.N/acre were ineffective in supplying nitrogen much in excess of that normally occurring in unfertilized tissues. Woss Camp tissues showed a decrease in nitrogen uptake but an increase in phosphorus uptake as a result of urea applications. Thus this area, quite possibly, could use application rates in excess of 200 lb.N/acre.

Urea applications brought about increases in soil nitrogen, pH, adsorbed ammonium and cation exchange capacity, particularly in the surface litter materials. The soils of each area showed some differences in response

to urea applications; the greatest response took place at Jeune Landing and Port Renfrew, and the least at Woss Camp. Precipitation and temperature differences for the three areas probably played an important role in the differences recorded.

The variability of the results obtained in this study confirm the urgency for continuing fertilizer studies in forest management programs. Since applications of less than 200 lb.N/acre were ineffective, future fertilizer studies could profitably include fewer but greater rates of treatments, in excess of 400 lb.N/acre, particularly if urea is to be used. In addition, as suggested by others (5), the adverse effects of increased nitrogen on the uptake of phosphorus, as reported in this study, could be reduced by additions of this nutrient in the added fertilizer. In addition, treatment replications should be increased to at least five because of the heterogeneous nature of forest soils and climatic conditions. There is a continuing need for detailed studies on the effects of reaction-products of urea and other nitrogen carriers on the various important soil properties to determine the best source of the nutrient and to evaluate its influence on the soil environment. Such studies could best be carried out under controlled conditions. In future fertilizer studies, the importance of the external climatic and weather factors should not be overlooked in the selection of trial sites. Environmental records such as air and soil temperatures, total and effective precipitation, air humidity, light intensity, elevation and length of growing season should be kept.

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Table 1. Content of N, P and K, as percentages of tissue dry weight, in spring and fall tissues.

| Treatment     | Nitrogen       |              |                  |                | Phosphorus     |              |                  |                | Potassium      |              |                  |                |
|---------------|----------------|--------------|------------------|----------------|----------------|--------------|------------------|----------------|----------------|--------------|------------------|----------------|
|               | Twig<br>spring | Twig<br>fall | Needle<br>spring | Needle<br>fall | Twig<br>spring | Twig<br>fall | Needle<br>spring | Needle<br>fall | Twig<br>spring | Twig<br>fall | Needle<br>spring | Needle<br>fall |
| Jeune Landing |                |              |                  |                |                |              |                  |                |                |              |                  |                |
| 0#N           | 0.38           | 0.70         | 0.83             | 1.34           | 0.07           | 0.12         | 0.13             | 0.21           | 0.20           | 0.26         | 0.27             | 0.49           |
| 50#N          | 0.36           | 0.72         | 0.85             | 1.45           | 0.07           | 0.12         | 0.13             | 0.20           | 0.20           | 0.25         | 0.31             | 0.50           |
| 100#N         | 0.36           | 0.73         | 0.82             | 1.47           | 0.07           | 0.11         | 0.13             | 0.16           | 0.19           | 0.25         | 0.28             | 0.40           |
| 200#N         | 0.38           | 0.81         | 0.84             | 1.79           | 0.07           | 0.11         | 0.13             | 0.17           | 0.18           | 0.25         | 0.30             | 0.38           |
| 400#N         | 0.38           | 0.92         | 0.91             | 2.08           | 0.07           | 0.12         | 0.13             | 0.16           | 0.17           | 0.28         | 0.31             | 0.45           |
| Woss Camp     |                |              |                  |                |                |              |                  |                |                |              |                  |                |
| 0#N           | 0.65           | 0.69         | 1.00             | 1.58           | 0.10           | 0.09         | 0.13             | 0.14           | 0.19           | 0.20         | 0.26             | 0.31           |
| 50#N          | 0.61           | 0.46         | 1.00             | 0.97           | 0.10           | 0.09         | 0.14             | 0.19           | 0.20           | 0.18         | 0.29             | 0.28           |
| 100#N         | 0.70           | 0.54         | 1.10             | 1.17           | 0.10           | 0.08         | 0.14             | 0.15           | 0.23           | 0.18         | 0.30             | 0.30           |
| 200#N         | 0.64           | 0.57         | 1.02             | 1.32           | 0.10           | 0.09         | 0.14             | 0.15           | 0.19           | 0.21         | 0.27             | 0.31           |
| Port Renfrew  |                |              |                  |                |                |              |                  |                |                |              |                  |                |
| 0#N           | 0.67           | 0.59         | 1.08             | 1.32           | 0.11           | 0.11         | 0.17             | 0.24           | 0.25           | 0.25         | 0.33             | 0.49           |
| 50#N          | 0.60           | 0.61         | 1.05             | 1.37           | 0.10           | 0.10         | 0.18             | 0.23           | 0.22           | 0.29         | 0.35             | 0.49           |
| 100#N         | 0.68           | 0.64         | 1.11             | 1.51           | 0.11           | 0.10         | 0.17             | 0.22           | 0.26           | 0.25         | 0.36             | 0.49           |
| 200#N         | 0.63           | 0.65         | 1.01             | 1.55           | 0.10           | 0.10         | 0.17             | 0.20           | 0.24           | 0.23         | 0.34             | 0.47           |
| 400#N         | 0.68           | 0.73         | 1.09             | 1.85           | 0.11           | 0.10         | 0.18             | 0.20           | 0.24           | 0.25         | 0.36             | 0.47           |

Table 2. Levels of N, P and K in fall needle and twig tissues from fertilized plots and expressed in terms of nutrient values in control tissues.

| Treatment     | Nitrogen |        | Phosphorus |        | Potassium |        |
|---------------|----------|--------|------------|--------|-----------|--------|
|               | twig     | needle | twig       | needle | twig      | needle |
| Jeune Landing |          |        |            |        |           |        |
| 0#N           | 100      | 100    | 100        | 100    | 100       | 100    |
| 50#N          | 103      | 108    | 100        | 95     | 96        | 102    |
| 100#N         | 104      | 110    | 92         | 76     | 94        | 82     |
| 200#N         | 116      | 134    | 92         | 81     | 96        | 78     |
| 400#N         | 131      | 155    | 100        | 76     | 108       | 92     |
| Woss Camp     |          |        |            |        |           |        |
| 0#N           | 100      | 100    | 100        | 100    | 100       | 100    |
| 50#N          | 67       | 62     | 108        | 131    | 89        | 88     |
| 100#N         | 78       | 75     | 97         | 106    | 91        | 95     |
| 200#N         | 83       | 84     | 102        | 108    | 105       | 97     |
| Port Renfrew  |          |        |            |        |           |        |
| 0#N           | 100      | 100    | 100        | 100    | 100       | 100    |
| 50#N          | 103      | 104    | 97         | 96     | 116       | 100    |
| 100#N         | 108      | 114    | 97         | 92     | 104       | 102    |
| 200#N         | 110      | 117    | 90         | 84     | 97        | 96     |
| 400#N         | 124      | 139    | 94         | 83     | 100       | 95     |

Table 3. Effect of urea applications on total soil nitrogen values (% of dry weight).

| Depth<br>inches | Treatment - Nitrogen Applied - lb/acre |            |             |             |             |
|-----------------|--|------------|-------------|-------------|-------------|
|                 | Control                                | 50 lb/acre | 100 lb/acre | 200 lb/acre | 400 lb/acre |
| Jeune Landing   |  |            |             |             |             |
| 4-0 (litter)    | 1.16                                   | 0.89       | 1.21        | 1.35        | 1.44        |
| 0-2             | 0.47                                   | 0.39       | 0.60        | 0.69        | 0.82        |
| 2-6             | 0.29                                   | 0.31       | 0.40        | 0.49        | 0.52        |
| 6-12            | 0.21                                   | 0.23       | 0.34        | 0.38        | 0.32        |
| Woss Camp       |  |            |             |             |             |
| 5-0             | 1.21                                   | 1.02       | 1.10        | 1.20        | -           |
| 0-2             | 0.25                                   | 0.28       | 0.25        | 0.35        | -           |
| 2-6             | 0.28                                   | 0.21       | 0.20        | 0.22        | -           |
| 6-12            | 0.21                                   | 0.17       | 0.14        | 0.17        | -           |
| Port Renfrew    |  |            |             |             |             |
| 4-0             | 0.96                                   | 1.00       | 1.26        | 1.21        | 1.41        |
| 0-2             | 0.31                                   | 0.17       | 0.34        | 0.27        | 0.28        |
| 2-6             | 0.31                                   | 0.19       | 0.28        | 0.14        | 0.22        |
| 6-12            | 0.19                                   | 0.17       | 0.24        | 0.15        | 0.18        |

Table 4. The influence of urea on the water and salt extractable cations and on exchangeable ammonium and cation exchange capacity.

| Depth<br>inches | N-applied<br>lb/acre | Jeune Landing                  |      |      |                                  |     |     |                    | C.E.C. <sup>1</sup> |
|-----------------|----------------------|--------------------------------|------|------|----------------------------------|-----|-----|--------------------|---------------------|
|                 |                      | Ca                             | Mg   | K    | Ca                               | Mg  | K   | NH <sub>4</sub> -N |                     |
|                 |                      | meg/100 g                      |      |      |                                  |     |     |                    |                     |
|                 |                      | H <sub>2</sub> O - extractable |      |      | NH <sub>4</sub> Cl - extractable |     |     |                    |                     |
| 4-0             | 0                    | 0.85                           | 0.39 | 0.85 | 26.0                             | 2.5 | 0.4 | 0.5                | 32.7                |
| "               | 50                   | 0.43                           | 0.25 | 0.54 | 19.3                             | 2.1 | 0.3 | 1.0                | 30.2                |
| "               | 100                  | 0.07                           | 0.11 | 0.35 | 21.4                             | 4.8 | 1.2 | 3.6                | 38.2                |
| "               | 200                  | 0.07                           | 0.06 | 0.24 | 21.0                             | 5.9 | 1.5 | 8.2                | 41.8                |
| "               | 400                  | 0.07                           | 0.04 | 0.18 | 22.0                             | 5.2 | 1.5 | 12.3               | 46.4                |
| 0-2             | 0                    | 0.20                           | 0.09 | 0.08 | 4.4                              | 1.7 | 0.2 | -                  | 13.4                |
| "               | 50                   | 0.38                           | 0.15 | 0.08 | 9.6                              | 1.4 | 0.2 | -                  | 14.9                |
| "               | 100                  | 0.46                           | 0.19 | 0.17 | 7.2                              | 1.8 | 0.2 | -                  | 14.2                |
| "               | 200                  | 0.25                           | 0.08 | 0.16 | 9.3                              | 2.5 | 0.3 | -                  | 19.2                |
| "               | 400                  | 0.05                           | 0.01 | 0.11 | 6.4                              | 2.1 | 0.1 | -                  | 21.9                |
| 2-6             | 0                    | 0.11                           | 0.09 | 0.02 | 1.9                              | 0.6 | 0.1 | -                  | 9.0                 |
| "               | 50                   | 0.11                           | 0.15 | 0.02 | 2.5                              | 1.0 | 0.1 | -                  | 11.2                |
| "               | 100                  | 0.16                           | 0.11 | 0.06 | 3.9                              | 0.9 | 0.1 | -                  | 10.9                |
| "               | 200                  | 0.17                           | 0.17 | 0.07 | 3.7                              | 1.5 | 0.1 | -                  | 16.1                |
| "               | 400                  | 0.50                           | 0.69 | 0.12 | 4.3                              | 1.8 | 0.1 | -                  | 15.5                |
| 6-12            | 0                    | 0.11                           | 0.05 | 0.04 | 1.3                              | 0.3 | -   | -                  | 5.9                 |
| "               | 50                   | 1.78                           | 0.05 | 0.03 | 2.5                              | 0.3 | -   | -                  | 6.2                 |
| "               | 100                  | 0.59                           | 0.12 | 0.05 | 3.1                              | 0.2 | -   | -                  | 7.1                 |
| "               | 200                  | 0.09                           | 0.06 | 0.06 | 1.5                              | 0.5 | -   | -                  | 11.9                |
| "               | 400                  | 0.19                           | 0.13 | 0.05 | 2.7                              | 0.7 | -   | -                  | 12.3                |

<sup>1</sup> Cation exchange capacity.

Table 4 - Cont'd.

| Depth<br>inches | N-applied<br>lb/acre | Woss Camp                      |      |      |                                  |     |     |                    |        |
|-----------------|----------------------|--------------------------------|------|------|----------------------------------|-----|-----|--------------------|--------|
|                 |                      | Ca                             | Mg   | K    | Ca                               | Mg  | K   | NH <sub>4</sub> -N | C.E.C. |
|                 |                      | meg/100 g                      |      |      |                                  |     |     |                    |        |
|                 |                      | H <sub>2</sub> O - extractable |      |      | NH <sub>4</sub> Cl - extractable |     |     |                    |        |
| 5-0             | 0                    | 0.20                           | 0.05 | 0.55 | 17.7                             | 4.5 | 1.2 | 0.5                | 47.6   |
| "               | 50                   | 0.52                           | 0.14 | 1.15 | 22.5                             | 5.0 | 1.0 | 1.0                | 48.4   |
| "               | 100                  | 0.43                           | 0.10 | 1.06 | 17.7                             | 4.9 | 1.0 | 3.4                | 48.4   |
| "               | 200                  | 0.22                           | 0.06 | 0.68 | 16.9                             | 5.0 | 1.3 | 6.4                | 48.4   |
| 0-2             | 0                    | 0.36                           | 0.20 | 0.19 | 1.4                              | 0.3 | 0.2 | -                  | 5.6    |
| "               | 50                   | 0.09                           | 0.05 | 0.11 | 3.6                              | 0.6 | 0.2 | -                  | 7.3    |
| "               | 100                  | 0.05                           | 0.04 | 0.08 | 1.0                              | 0.3 | 0.2 | -                  | 4.3    |
| "               | 200                  | 0.05                           | 0.04 | 0.23 | 1.7                              | 0.8 | 0.3 | -                  | 8.4    |
| 2-6             | 0                    | 0.21                           | 0.16 | 0.07 | 1.4                              | 0.3 | 0.1 | -                  | 4.9    |
| "               | 50                   | 0.08                           | 0.05 | 0.03 | 1.7                              | 0.3 | 0.1 | -                  | 4.2    |
| "               | 100                  | 0.04                           | 0.03 | 0.02 | 0.5                              | 0.1 | -   | -                  | 2.9    |
| "               | 200                  | 0.04                           | 0.03 | 0.04 | 0.7                              | 0.2 | 0.1 | -                  | 3.3    |
| 6-12            | 0                    | 0.05                           | 0.02 | 0.05 | 1.7                              | 0.2 | -   |                    | 4.8    |
| "               | 50                   | 0.09                           | 0.04 | 0.06 | 1.8                              | 0.3 | 0.1 |                    | 3.4    |
| "               | 100                  | 0.04                           | 0.03 | 0.04 | 2.8                              | 0.1 | 0.1 |                    | 0.9    |
| "               | 200                  | 0.06                           | 0.03 | 0.08 | 0.9                              | 0.2 | 0.1 |                    | 3.0    |

Table 4 - Cont'd.

| Depth<br>inches | N-applied<br>lb/acre | Port Renfrew                   |      |      |                                  |     |     |                    | C.E.C. |
|-----------------|----------------------|--------------------------------|------|------|----------------------------------|-----|-----|--------------------|--------|
|                 |                      | Ca                             | Mg   | K    | Ca                               | Mg  | K   | NH <sub>4</sub> -N |        |
|                 |                      | meg/100 g                      |      |      |                                  |     |     |                    |        |
|                 |                      | H <sub>2</sub> O - extractable |      |      | NH <sub>4</sub> Cl - extractable |     |     |                    |        |
| 4-0             | 0                    | 0.18                           | 0.33 | 0.63 | 14.6                             | 4.4 | 0.6 | 0.2                | 25.8   |
| "               | 50                   | 0.15                           | 0.21 | 0.38 | 15.2                             | 4.8 | 0.6 | 0.5                | 27.0   |
| "               | 100                  | 0.07                           | 0.13 | 0.38 | 19.7                             | 5.9 | 1.0 | 2.8                | 35.6   |
| "               | 200                  | 0.12                           | 0.06 | 0.41 | 16.6                             | 7.3 | 1.3 | 10.9               | 52.8   |
| "               | 400                  | 0.17                           | 0.06 | 0.34 | 18.1                             | 9.2 | 1.4 | 21.6               | 65.2   |
| 0-2             | 0                    | 0.05                           | 0.06 | 0.10 | 0.8                              | 0.3 | 0.3 | -                  | 4.3    |
| "               | 50                   | 0.05                           | 0.04 | 0.04 | 0.3                              | 0.2 | 0.1 | -                  | 4.3    |
| "               | 100                  | 0.04                           | 0.03 | 0.05 | 0.5                              | 0.2 | 0.1 | -                  | 5.0    |
| "               | 200                  | 0.03                           | 0.03 | 0.04 | 0.3                              | 0.2 | 0.1 | -                  | 5.6    |
| "               | 400                  | 0.11                           | 0.04 | 0.04 | 0.8                              | 0.4 | 0.1 | -                  | 5.2    |
| 2-6             | 0                    | 0.03                           | 0.05 | 0.03 | 0.2                              | 0.3 | 0.1 | -                  | 4.5    |
| "               | 50                   | 0.03                           | 0.03 | 0.03 | 0.1                              | 0.1 | 0.1 | -                  | 2.5    |
| "               | 100                  | 0.03                           | 0.02 | 0.02 | 0.3                              | 0.1 | 0.1 | -                  | 3.9    |
| "               | 200                  | 0.02                           | 0.02 | 0.01 | 0.1                              | 0.1 | 0.1 | -                  | 3.3    |
| "               | 400                  | 0.02                           | 0.03 | 0.01 | 0.2                              | 0.2 | 0.1 | -                  | 5.4    |
| 6-12            | 0                    | 0.03                           | 0.03 | 0.05 | 0.1                              | 0.1 | 0.1 | -                  | 3.5    |
| "               | 50                   | 0.03                           | 0.02 | 0.04 | 0.1                              | -   | 0.1 | -                  | 1.7    |
| "               | 100                  | 0.04                           | 0.03 | 0.07 | 0.1                              | -   | 0.1 | -                  | 2.5    |
| "               | 200                  | 0.03                           | 0.02 | 0.04 | 0.1                              | -   | 0.1 | -                  | 2.0    |
| "               | 400                  | 0.05                           | 0.03 | 0.05 | 0.1                              | 0.1 | 0.1 | 0                  | 4.6    |

Table 5. Modifications in soil pH values as a result of urea applications.

| Depth<br>inches | Treatment | pH            |           |              |
|-----------------|-----------|---------------|-----------|--------------|
|                 |           | Jeune Landing | Woss Camp | Port Renfrew |
| (L-H)           | 0#N       | 4.7           | 5.3       | 4.3          |
| 0-2             |           | 4.6           | 5.3       | 4.3          |
| 2-6             |           | 4.6           | 4.8       | 4.7          |
| 6-12            |           | 4.8           | 5.0       | 5.0          |
| (L-H)           | 50#N      | 4.7           | 4.5       | 4.3          |
| 0-2             |           | 4.8           | 5.1       | 4.5          |
| 2-6             |           | 5.3           | 5.1       | 5.0          |
| 6-12            |           | 5.3           | 5.2       | 5.1          |
| (L-H)           | 100#N     | 5.0           | 4.3       | 4.8          |
| 0-2             |           | 4.8           | 4.9       | 4.5          |
| 2-6             |           | 4.6           | 5.1       | 4.8          |
| 6-12            |           | 4.4           | 5.4       | 5.1          |
| (L-H)           | 200#N     | 5.0           | 4.7       | 5.7          |
| 0-2             |           | 4.8           | 4.6       | 5.1          |
| 2-6             |           | 4.6           | 4.9       | 5.1          |
| 6-12            |           | 4.4           | 5.1       | 5.5          |
| (L-H)           | 400#N     | 5.7           | -         | 6.2          |
| 0-2             |           | 5.1           | -         | 4.4          |
| 2-6             |           | 4.7           | -         | 4.6          |
| 6-12            |           | 4.6           | -         | 5.0          |

Table 6. Total monthly precipitation and mean temperature records for the three study areas (1968).

| Location      | Precipitation (inches) |     |     |     |     |       | Temperature (F°) |    |    |    |    |
|---------------|------------------------|-----|-----|-----|-----|-------|------------------|----|----|----|----|
|               | A.*                    | M.  | J.  | J.  | A.  | Total | A.               | M. | J. | J. | A. |
| Jeune Landing | 4.0                    | 3.5 | 4.1 | 2.1 | 2.4 | 16.1  | 54               | 60 | 54 | 64 | 60 |
| Woss Camp     | 2.2                    | 1.9 | 1.3 | 1.7 | 2.0 | 9.1   | 46               | 58 | 58 | 68 | 65 |
| Port Renfrew  | 7.2                    | 2.5 | 6.5 | 3.0 | 7.2 | 26.4  | 47               | 56 | 56 | 62 | 60 |

\* Since the fertilizer was applied during the last two weeks of April (1968), only precipitation falling during the 15th to 30th of April has been recorded.