INFLUENCE OF NITROGEN SUPPLY ON THE GROWTH AND BRANCHING HABIT OF *PINUS RADIATA* SEEDLINGS

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SYNOPSIS

In a glasshouse pot trial, radiata pine (Pinus radiata *D.Don) seedlings raised and grown in a nitrogen (N)-deficient soil for 16 months were grown for the next 17 months with five levels of N supply, namely, 0, 25, 50, 75, and 100 ppm N.*

Nitrogen supply markedly affected the form of the seedlings through its effect on branch development. The net length of lateral branches per seedling, as well as the mean number of whorls and branches per seedling, increased with increasing level of N supply. Lateral branching in the N-deficient control seedlings was minimal with net mean branch length of about 2 cm/seedling — i.e., *7% of mean stem height. By contrast, the heavily branched seedlings of the highest N treatment produced branches totalling nearly 67 cm in length* — i.e., *100% of mean stem height.*

Seedling height at time of harvest was positively correlated with N supply up to the 75 ppm level of supply. While seedlings grown with 100 ppm N supply attained only three-quarters of the mean height of the crop grown with the 75 ppm N rate, the crop yields of dry matter were comparable.

INTRODUCTION

Will (1971), in experiments with radiata pine seedlings and young trees, observed that branch development is markedly affected by the level of N supply, and noted that marginal N deficiency inhibits branch and stem diameter growth more than it does stem height growth. He also warned that undesirable side-effects, such as heavier branch growth and reduced leader dominance, could result where nitrogen fertilizers are used indiscriminately to promote the overall growth rate of young pines.

When 10 pots containing 16-month-old, N-deficient radiata pine seedlings growing in an N-deficient soil became redundant to one project, it was decided that the material could be used to study further the effects of different levels of N supply on the growth and branching habit of the seedlings.

METHODS

At the start of the glasshouse trial in November 1970, the pine seedlings were 16 months old. They were growing, eight

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seedlings to a pot, in ten 5.7 litre plastic pots having basal drainage holes. Each pot contained the equivalent of 3.5 kg oven-dry soil collected from Putauaki (NZMS grid ref. 77/155057) in Tarawera Forest. The soil was taken from the 10 to 12 cm thick, black organic horizon which lies buried beneath *ca.*30 cm scoria erupted from Mt. Tarawera in 1886. The various properties of this paleosol have been described by Birrell *et al.* (1971).

Five treatments (with two pots per treatment) were imposed on the seedlings for 17 months. The treatments consisted of five levels of N supply — 0, 25, 50, 75, and 100 ppm N. This was applied by flushing the pots with a series of nutrient solutions which differed only in their urea content.

Each week a basal nutrient solution with the composition shown in Table 1 was freshly prepared from concentrated stock solutions. Appropriate weights of urea were then dissolved in separate portions of this solution to provide a series of solutions with the requisite N concentrations.

TABLE 1: CHEMICAL COMPOSITION OF THE NUTRIENT SOLUTION (ppm)

Element	*Concentration*	*Element*	*Concentration*
P	1	B	0.50
K	20	Mn	0.50
Ca	50	Fe	0.05
Mg	10	Cu	0.02
S	21.62	Zn	0.05
		Mo	0.01

The solutions were applied to the soil surface of the pots twice weekly in sufficient quantity to ensure that the soil was thoroughly wetted and that a surplus drained to waste. Seedling heights were measured at monthly intervals. At harvest, seedling heights, the number of branches per seedling by whorls, number of whorls per seedling, and individual branch lengths were recorded. The seedlings were then divided into roots, stems, stem foliage, and branches plus attached needles. These were oven-dried, weighed, and analysed for N content.

RESULTS AND DISCUSSION

The relative effects which the five different N supply levels had on the growth and branching habit of the pine seedlings were most marked despite the minimal replication of treatments. The appearance of the pine seedlings shortly before harvest can be seen from Fig. 1. Figure 2 shows the distinctive growth curve for each treatment when the mean seedling heights recorded at monthly intervals are plotted against time.

Treatment means for seedling height, crop dry weight, foliar N concentration, and selected branching variables at time of harvest are summarized in Table 2. The optimal N supply level

TABLE 2: MEAN VALUES BY TREATMENTS FOR SELECTED SEEDLING VARIABLES

Standard deviations shown in parentheses are based on 16 observations except for the crop dry weights which are based on two observations only.

	Treatment				
	0	*25*	*50*	*75*	*100*
Mean net branch length/seedling (cm)	2.1	16.4	34.7	30.8	66.8
S.D.	(± 2.9)	(±14.1)	(±31.5)	(±21.0)	(±43.8)
Mean net No. of branches/seedling	2.4	6.1	7.0	8.5	12.5
S.D.	(± 2.3)	(± 3.3)	(± 3.8)	(± 5.9)	(± 6.6)
Mean net No. of whorls/seedling	0.9	2.5	2.6	2.9	3.7
S.D.	(± 0.6)	(± 1.0)	(± 0.8)	(± 1.2)	(± 1.6)
Mean net branch length/seedling height ratio	0.06	0.24	0.47	0.42	0.94
S.D.	(±0.06)	(±0.18)	(±0.40)	(±0.32)	(±0.40)
Mean seedling height (cm)	32.3	57.2	72.2	79.1	67.0
S.D.	(± 7.0)	(±13.4)	(±15.2)	(±16.6)	(±15.7)
Mean crop dry weight (g)	43	151	189	305	299
S.D.	(± 3)	(±28)	(±51)	(±26)	(±38)
Mean needle N concentration (%)	0.44	0.65	1.00	1.46	2.36
S.D.	(±0.08)	(±0.08)	(±0.11)	(±0.13)	(±0.12)

TABLE 3: LINEAR REGRESSION COEFFICIENTS, STANDARD ERRORS AND CORRELATION COEFFICIENTS FOR SEEDLING BRANCHING VARIABLES ON LEVEL OF N SUPPLY

Calculations based on 16 observations.

Dependent Variable Y	*Regression Coefficient b (slope)*	*S.E.*	*Regression Constant a*	*S.E.*	*Correlation Coefficient r*
Net branch length/seedling	0.575	±0.088	1.386	±3.123*	0.593***
No. of branches/seedling	0.090	±0.015	2.812	±0.529	0.563***
No. of whorls/seedling	0.024	±0.004	1.275	±0.134	0.591***
Net branch length/seedling, height ratio	0.008	±0.001	0.039	±0.037	0.644***

***Significant at 0.1% level.

*This high standard error is an expression of the wide variability in branch length coupled with minimal replication of treatments in this pilot trial.

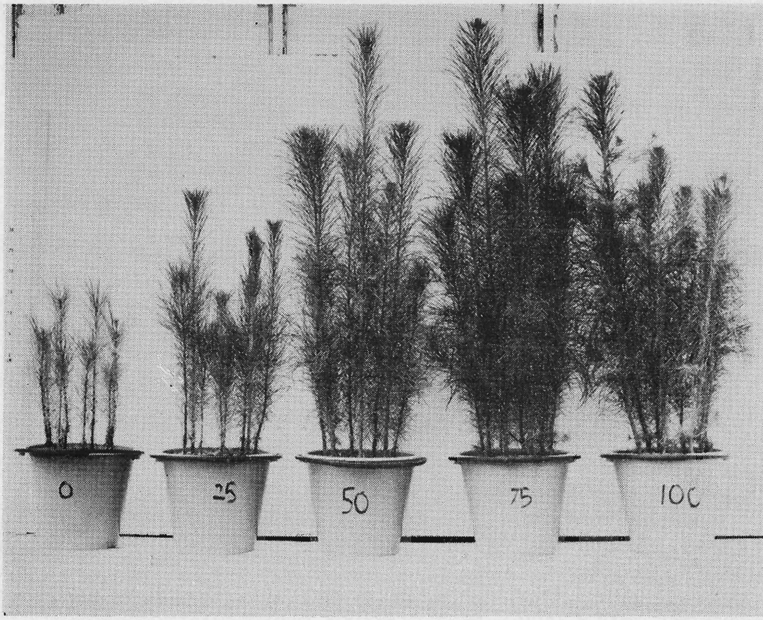

FIG. 1: *Photograph taken on 11 November 1971, one year after commencement of treatments, to illustrate the effects of the five different levels of N supply on the growth and branching characteristics of the* P. radiata *seedlings. The rates of N supply (ppm) are marked on the buckets.*

calculated from the seedling height on N supply level parabola was 69 $\pm$ 20 ppm. The wide limits are an expression of the limited replication of the trial. From the height data it is evident that the 75 ppm level of N supply produced the tallest seedlings. The highest level of N supply, however, produced seedlings with the greatest lateral branch development in terms of net length, branch net dry weight, and number of branches and whorls.

Examination of the net length of branches/seedling height ratio for each treatment (see Table 2) shows clearly that the relative proportion of lateral branch growth to stem height growth increased with increasing level of N supply and approached unity for the highest N treatment. The linear regression coefficients and highly significant correlation coefficient which relate N supply and the branch length/seedling height ratio are shown in Table 3.

Data from the trial support the observation of Will (1971) that a marginal N supply inhibits branch growth more than it inhibits stem height growth. At time of harvest, the mean seedling height and total branch length for seedlings grown with no applied N amounted to about 41% and 7%, respectively, of the corresponding values for the seedlings grown with the 75 ppm N supply. Seedlings grown with the 25 ppm

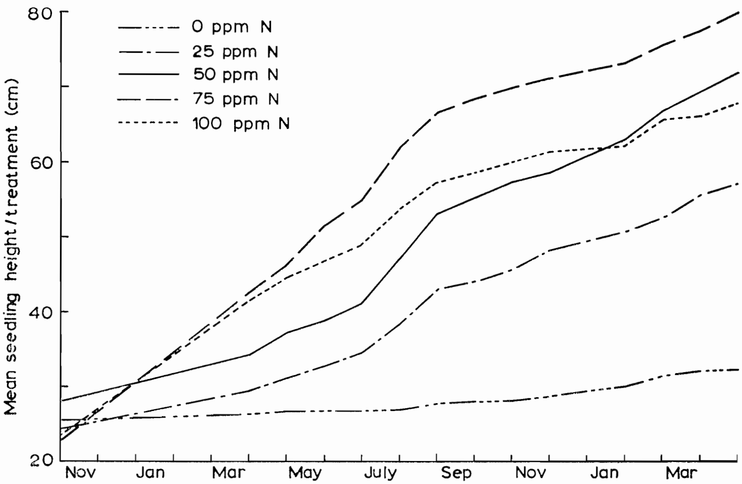

FIG. 2: *The effect of time and treatment on mean seedling height.*

N treatment attained 72% of the height and 53% of the total branch length of seedlings grown with the 75 ppm N treatment.

The branching variables measured for each individual seedling, at time of harvest, were: (a) net branch length, (b) net number of branches, and (c) number of whorls. As can be seen from the treatment means shown in Table 2, each of these variables generally increased with increasing level of N supply.

A statistical examination of the data on a seedling basis showed that the relationship between each of these three variables and level of N supply was linear and highly significant. The calculated linear regression coefficients and their standard errors for the equation $Y = a + b X$ are shown in Table 3.

Highly significant correlations were also found between level of N supply and both dry weights and N concentrations of the crops and their component parts. The simple correlations for these are shown in Table 4.

TABLE 4: SIMPLE CORRELATIONS BETWEEN LEVEL OF N SUPPLY AND (a) DRY WEIGHTS, AND (b) N CONCENTRATIONS OF THE SEEDLING CROPS AND THEIR COMPONENT PARTS

Variable Y	*Correlation Coefficient (r)*	*Variable Y*	*Correlation Coefficient (r)*
Needle dry weight	0.861***	Needle N concentration	0.959***
Branch dry weight†	0.709***	Branch N concentration	0.895***
Stem dry weight	0.898***	Stem N concentration	0.900***
Root dry weight	0.948***	Root N concentration	0.827***
Seedling dry weight	0.935***	Seedling N concentration	0.948***

***Significant at 0.1% level.
†Includes attached foliage.

The regression of total crop N uptake on N supply level is given by the equation:

Crop N uptake $(Y) = 0.043 \times$ level of N supply (ppm) — 0.255 ($r = 0.947^{***}$).

CONCLUSIONS

(1) The level of N supply is an important factor in determining the branching characteristics of *Pinus radiata* seedlings. This study showed that the number of lateral branches, the number of whorls, and the net length of lateral branches per plant were each highly significantly and positively correlated with N supply.

(2) The level of N supply also influences the relative distribution of growth between the main stem and lateral branches. Data recorded at time of harvest show that the net length of lateral branches generally increased relative to seedling height as N supply increased. With the highest level of supply this ratio was close to unity. The ratio of net lateral branch length/stem height was highly significantly and positively correlated with level of N supply.

(3) The 75 ppm N supply level produced the tallest seedlings. The greater lateral branch development promoted by the highest N supply rate appeared to be at the expense of seedling height growth. From the seedling harvest height on N supply level parabola the optimum supply rate was calculated to be 69 $\pm$ 20 ppm N*. Although, on average, the seedlings grown with 100 ppm N supply attained only three-quarters of the mean height of the crop grown with the 75 ppm supply, crop yields for these two treatments were comparable.

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*The broad limits reflect the appreciable height variability within replicates and could probably be reduced by more extensive replication.