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Effects of Nutrient Deficiencies on the Root Regenerating Potential and Growth of *Pinus caribaea* and *Pinus kesiya* Seedlings

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ABSTRAK

Kejayaan penubuhan ladang bergantung kepada pengeluaran anak-anak benih yang berpotensi tinggi untuk pertumbuhan akar baru dan ditanam di kawasan yang subur bagi menggalakkan tumbesaran akar itu. Banyak fakta di tapak semaian dan ladang mempengaruhi potensi pertumbuhan akar (PPA). Penyelidikan ini ditumpukan kepada kesan kekurangan dua zat galian penting yang diperlukan oleh tumbuhan-tumbuhan, nitrogen (N) dan/atau fosforus (P) yang selalunya berkurangan di tanah tropika, pada PPA dan tumbesaran anak benih Pinus caribaea *dan* Pinus kesiya. *Anak benih* P. caribaea *dan* P. kesiya *yang mendapati zat galian dengan cukup tidak terbantut daripada mengeluarkan akar baru selepas dipangkas akar dan dipindahkan ke kawasan yang kurang zat galian (-N, -P & -NP). Selepas pemindahan, pokok yang mendapati semua zat galian (F) dan yang kurang P menunjukkan ketinggian dan perepang batang yang lebih berbanding dengan yang kurang N dan NP. Hasil kajian juga menunjukkan bahawa* P. kesiya *mempunyai PPA yang lebih tinggi daripada* P. caribaea *walaupun spesies pertama itu lebih rendah ketinggiannya pada permulaan eksperimen. Implikasi praktik hasil penyelidikan kepada amalan di tapak semaian dan penubuhan pokok di ladang dibincangkan.*

ABSTRACT

Successful plantation establishment requires the production of seedlings with high root regenerating potential (RRP) to be planted in an enviroment which facilitates the production of new roots. Numerous factors in the nursery and in the field influence RRP. This study examines the effects of a deficiency of two important essential elements, nitrogen and/or phosphorus commonly deficient in tropical soils, on the RRP and growth of Pinus caribaea *and* Pinus kesiya *seedlings. Given an adequate supply of nutrients before transplanting in nutrient deficient sites,* P. caribaea *and* P. kesiya *showed a high capacity to regenerate root following root pruning and replanting into conditions of limited nutrient supply (-N, -P & -NP). Seedlings grown in F (full nutrients) and -P conditions were taller and had thicker stem diameter than in -N or -NP. The results also show that* P. kesiya *had a higher RRP than* P. caribaea *despite the shorter mean height of the former species at the start of the experiment. The practical implication of the results to nursery cultural practices and tree establishment is discussed.*

INTRODUCTION

The problems of poor growth due to low soil fertility are more frequent and serious in the establishment of plantation forests then agricultural crops because the lands relegated to forestry are often too infertile for agricultural use (Abod 1980). Such problems are more common in the tropics where soils are generally deficient in many essential nutrients (Thompson and Troeh 1973) particularly nitrogen (N) and phosphorus (P) (Gourou 1966; Kalpage 1974) necessary for healthy vigorous growth of trees.

Pinus caribaea Mor. var. *hondurensis* B & G and *Pinus kesiya* Royle ex Gordon are two species with considerable potential for planting in tropical and subtropical areas (Lamb. 1973; Abod 1980) but much of the technology being applied in their establisment is adapted from a knowledge of species of more temperate origin. A better understanding of their growth pattern and requirements are required in order to develop optimum cultural practices for plantation establisment in the tropics.

A number of workers (Stone and Schubert 1959; Abod *et al.* 1979; Abod and Wesbter 1989; 1990) have stressed that the initial survival of planted seedlings depends chiefly on the ability of their root system to regenerate in the first few weeks after outplanting to re-establish contact with the surrounding soil mass and begin taking up water and nutrients. The work described here examines the effects of deficiency in N, P, or both on growth, with particular emphasis on the root growth capacity of seedlings of *P. caribaea* and *P. kesiya.* It could have a useful practical application to know whether any deficieny in these nutrient elements could significantly affect these species to regenerate roots vital for successful establishment in the first critical month after outplanting.

MATERIALS AND METHODS

Pinus kesiya, a montane species, and *Pinus caribaea* variety *hondurensis,* a lowland species were used. *P. kesiya* seeds collected near Agapang, Luzon, Philippines (lat. 17°33' N., long 120°57' E., elev. 1300 m) were obtained from the Division of Forest Research, CSIRO, Canberra. *P. caribaea* seeds were collected by the Queensland Department of Forestry from a plantation at Maryvale, Queensland, which had been planted originally with seed from the lowland coastal plain of Belize.

Seeds were germinated and grown individually in plastic pots (15 cm diam.) containing 1:1 vermiculite-perlite mix, which was kept well supplied with water and nutrients. The seedlings were free of any associated mycorrhizal fungi. Plants were grown in LB growth cabinet (Pescod *et al.* 1963) with a day/night temperature of 27/22°C which was synchronized with a day length of 12 hours throughout the experiment.

Temperatures in the LB growth cabinet could be controlled precisely within the range 0-35°C programmed for separate day and night temperatures. Relative humidity was not controlled but was recorded to be above 50% throughout the duration of the experiment. Twenty-eight fluorescent and four incandescent lamps provided a light intensity of 80 watts per metre square at plant height. The lamps were connected to a time switch for photoperiodic control.

At the commencement of the experiment, uniform sized seedlings 14-week-old and averaging 12.0 cm tall and 0.26 cm root collar diameter for *P. caribaea* and 10.0 cm tall and 0.26 cm root collar diameter for *P. kesiya* were selected. Seedling variations were less then 0.5 cm tall and 0.02 cm thick for either species. Preliminary trials had confirmed this to be essential to reduce to acceptable limits, the great variability of the results for root regeneration. Similar problems with variability in root regeneration were noted by Stone *et al.* (1962). Space limitations allowed only eight replicates to be used i.e. 2 species x 4 nutrient treatments x 8 replicates.

Roots of all seedlings were pruned to a standard length and all white root tips pinched off to simplify recognition of new roots. The plants were grown for 4 weeks in full nutrient (F), minus nitrogen (-N), minus phosphorus (-P), and minus N and P (-NP). Plants were given these nutrients in the morning and distilled water in the afternoon. After 4 weeks, they were harvested for measurements of height and diameter increment, root regeneration, and root and shoot oven dry weight. Any morphological differences in the shoots between treatmens were compared.

The technique of Stone and colleagues (see review by Stone 1967) was used to assess the root regenerating potential of the plants. All white root tips greater than 1 cm long were counted and those greater than 2 cm were measured. Root regenerating potential is determined from both the total number (N) and length (L) of new roots per plant.

All data were subjected to analysis of

variance and the significance of differences between group means was tested with Duncan's new multiple range test (Steel and Torrie 1960; Winer 1971).

RESULTS

The results of analysis of variance are given in Table 1 for the parameters measured in the experiment. These was no interaction between nutrients and species indicating a similar response to nutrient treatment in both species.

No colour difference was observed in the foliage between different treatments for each species at harvest.

Root regeneration

Root regenerating potential (RRP) based on both number and length of new roots showed no significant difference between treatment means for nutrient treatments. However, there was a highly significant species difference (Table 1) due to *P. kesiya* producing more and longer new roots in each treatment (Table 2).

Dry weight

There were no significant difference in total root and total plant dry weights between the nutrient treatments or between species although there were differences in shoot dry weight for both factors (Table 1).

Table 2 shows that shoot dry weight in -P treatment was significantly greater than -NP but was not significantly different from F and -N. As the -NP treatment did not differ significantly from full nutrient this results is difficult to explain. These dry weight differences would need to be regarded with caution as the treatment period was only 4 weeks and the pre-treatment dry weight would far exceed the dry weight increment during this period. For example, *P. kesiya* produced more and longer new roots than *P. caribaea* in each treatment with lack of difference in total root dry weight. This may be attributed to the original mass of roots which far exceed the newly-produced roots.

Height and Diameter Increment

Both height and diameter increment showed significant differences between nutrient treatment means and between species (Table 1). There was no significant difference for height increment between F and -P, and between -N and -NP treatments but F and -P

TABLE 1

Results of analysis of variance for significance of differences between treatment means for nutrients and species and the interaction between these

Parameter	Nutrients	species	Interaction (Nutrient x Species)
Root regneration (per plant)			
Total number of white roots > 1.0 cm long	NS	***	NS
Total length of white roots > 2.0 cm long	NS	***	NS
Dry weight (g)			
Root	NS	NS	NS
Shoot	*	*	NS
Total plant	NS	NS	NS
Increment (cm)			
Height	***	NS	NS
Root collar diameter	*	NS	NS

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; NS, not significant.

TABLE 2
Ranking of treatment means in ascending order for the different parameters for nutrients, species and their interaction.

Treatment	A: Root regeneration (per plant)				B: Dry weight (g)						C: Height & Diameter Increment (cm)			
	Total number (N) of white roots > 1.0 cm long		Total length (L) of white roots > 2.0 cm long		Root (R)		Shoot (S)		Total Plant (TP)		Height Increment (H)		Diameter Increment (D)	
Factor 1: Nutrients	–P	139	F	288	–NP	0.394	–NP	1.219	–NP	1.613	–N	1.4	–NP	0.05
	F	143	–P	295	F	0.414	F	1.332	F	1.745	–NP	1.4	–N	0.06
	–NP	148	–N	328	–N	0.450	–N	1.352	–N	1.803	–P	1.8	–P	0.07
	–N	152	–NP	330	–P	0.462	–P	1.600	–P	2.062	F	2.2	F	0.08
Factor 2: Species	PC	114	PC	238	PK	0.413	PC	1.273	PC	1.720	PC	1.7	PC	0.06
	PK	178	PK	383	PC	0.447	PK	1.479	PK	1.891	PK	1.7	PK	0.07
Interaction: Nut. x Spp.	Nut. Spp.	N	Nut. Spp.	L	Nut. Spp.	R	Nut. Spp.	S	Nut. Spp.	TP	Nut. Spp.	H	Nut. Spp.	D
	–P PC	86	–P PC	173	–NP PK	0.346	F PC	1.124	–NP PK	1.498	–NP PC	1.2	–NP PC	0.05
	–F PC	92	F PC	231	F PC	0.390	–NP PK	1.152	F PC	1.512	–N PC	1.4	–N PC	0.06
	–N PC	138	–NP PC	273	–N PK	0.399	–N PC	1.262	–NP PC	1.728	–N PK	1.4	–P PC	0.06
	–NP PC	138	–N PC	275	F PK	0.438	–NP PC	1.287	–N PC	1.765	–NP PK	1.5	–NP PK	0.06
	–NP PK	157	F PK	345	–NP PC	0.442	–P PC	1.419	–N PK	1.841	–P PC	1.8	–N PK	0.07
	–N PK	166	–N PK	381	–P PC	0.455	–N PK	1.442	–P PC	1.874	–P PK	1.8	–P PK	0.08
	–P PK	192	–NP PK	386	–P PK	0.469	F PK	1.540	F PK	1.978	F PK	2.0	F PK	0.08
	–F PK	194	–P PK	418	–N PC	0.502	–P PK	1.780	–P PK	2.249	F PC	2.3	F PC	0.09

Bracketed means are not significantly different ($P < 0.05$)

were both significantly greater than N and -NP treatments (Table 2).

For diameter increment, Table 2 shows that the increments in F and -P were both significantly greater than in -NP treatment. No significant difference was observed between F, P, and -N, and between -N and -NP treatments.

DISCUSSION

Within each species no significant difference in root regenerating potential (RRP) was found in any of the nutrient treatments.

Some effects on growth were observed. For example, *P. kesiya* seedlings grown in the -NP treatment had significantly less shoot dry weight than seedlings of this species grown in -P treatment; *P. caribaea* seedlings grown in full nutrients had significantly higher height increment than those grown in -N and -NP treatments and significantly higher diameter increment than those grown in -NP treatment. However, none of these treatments had significant effect on root regeneration although in *P. caribaea,* least root regeneration was found in the treatments (F and-P) giving best height growth. The possibility of competition for nutrients (particularly N) being involved in the balance between root and shoot growth must be borne in mind.

Under the conditions of the experiment, however, the results indicate that plants had adequate nutrient reserves at the commencement of the treatment for them not to be significantly affected over a 4-week nutrient deficiency treatment. The supply of N and P from the different parts of the plant, for example from old leaves to the growing roots, was unlikely to be restricted because of the high mobility of the elements. Bukovac and Wittwer (1957) in their study on the mobility of radioactively labelled mineral nutrients applied to leaves of bean plants, classified P to be one of the very mobile element. N can also be considered as a relatively mobile element as suggested by experiments on deciduous trees where in autumn a considerable part of the element is translocated into the twigs before abscission occurs (Kramer and Kozlowski 1979).

This study confirms that the nutritional status of seedlings is important in sustaining seedling growth, especially under poor nutrient conditions in the field, until such time as nutrient reserves in the soil can be tapped. The nutritional status of seedlings at the time of transplanting is largely determined by the availability of nutrients in the nursery soil (van den Driessche 1977). Newly-transplanted seedlings of *P. radiata* (Woods 1976) and *Picea abies* (L.) Karst. (Machek 1972) for example, have shown improved field performance in relation to the fertility of the soil in which they were grown. Seedling survival and height growth after transplanting may increase with improved fertility in nursery soil (Woods 1976) but the effect of this on immediate growth response, i.e., RRP has not been determined. In the field, it is difficult to ascertain whether nutrient application at the time of or after planting is more important to seedling performance than is nursery soil fertility. However, it is recognised that any factor which inhibits RRP in seedlings will reduce the chances of survival and maximum early growth (Sutton 1980; Abod and Webster 1989; 1990).

The results in this study indirectly support the recommendations of Endean (1967) and Brown and Hall (1968) in the use of fertilizers where they pointed out that plant RRP is not significantly affected when grown in a nutrient deficient condition for one month. Experiments of longer duration may be needed to determine the time period before distinct differences can be observed between nutrient deficient trees. The results is this experiment also show that *P. kesiya* is superior to *P. caribaea* in its capacity to regenerate roots despite the shorter mean height of the former species at the start of the experiment. It may be noted that Kha (1965) reported *P. kesiya* survives well in competition on sites which are poor in nutrients or badly degraded.

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