GROWTH AND PHYSIOLOGICAL EVALUATIONS OF PLANTED FOREST SPECIES ALONG A RECREATIONAL TRAIL

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ABSTRACT

The Keruing trail is the oldest established and one of the most popular nature trail in Forest Research Institute Malaysia (FRIM). It is about 532 m in distance, displaying many mature timber species such as *Neobalanocarpus heimii* (chengal), *Dyera costulata* (jelutong), *Dryobalanops aromatica* (kapur), *Dipterocarpus baudii* (keruing bulu), *Shorea leprosula* (meranti tembaga), *Shorea bracleolata* (meranti pa'ang) and others. Previous observations indicated deterioration in soil due to compaction, root exposure and health deterioration of mature trees. Five species of seedlings, namely *D. aromatica*, *D. costulata*, *Palaquium gutta*, *N. heimii* and *Intsia palembanica* were planted to test their response when subjected to frequent recreational trampling. Each species of seedling was planted in a row across the nature trail; an individual was planted at the centre and every meter from the centre of the trail (1st, 2nd, 3rd, 4th and 5th m). Along the trail, a different species was planted at every 20 m intervals. Species were repeated systematically, to yield five replicates for each species along the total length of the trail. The seedlings growth and development were monitored over a 4 year period. Results indicated that all species had slower growth closer to the centre of the trail. On the other hand, leaf fluorescence measured to determine the physiological efficiencies of each seedling showed that seedlings of *D. costulata* had the highest and most constant readings. In conclusion, the results indicated *D. aromatica* could not grow in compacted soil.

Keywords: soil compaction, chlorophyll fluorescence, physiological efficiency

INTRODUCTION

Chlorophyll fluorescence offers a rapid, accurate method to determine the health of trees. It works on the principle that photosynthesis is the main activity within plant biosynthesis that provides an interactive link between the internal metabolism of a tree and the external environment. On the other hand, reduction in photosynthetic capacity is often the initial symptoms of environmental stresses. Hence, assessing the integrity of the photosynthetic process provides a rapid and non-destructive diagnostic system of detecting and quantifying plant tolerance to environmental stresses.

Soil compaction has been documented in many urban soils and is acknowledged as a major impediment to establishment of trees in these areas. While in public parks and playgrounds, recreational trampling leave impacts on vegetation and soils conditions (Cole 1995; Leung & Marion 2000). The compaction level is further enhanced by man's activities like construction and traffic. Soils compaction studies in recreational areas often resulted in greater bulk density and reduced pore volumes than control areas (Liddle & Greig-Smith 1975; Cole 1986; Makhdoum & Khorasani 1988). Reports have shown that when soil bulk density increased, shoot growth and leaf size reduced (Masle 1992; Mulholland et al. 1999). On the other hand, Taylor and Brar (1991) noted that soil compaction reduced shoot growth by restricting the soil volume for root expansion and hence reduced the water and nutrients availability to plants in field condition.

Hence a study was developed to assess the impact of recreational activities on seedling regeneration at FRIM's Keruing Trail. This study tested the effects of recreational activities on soil compaction and seedling growth and development in the trail. It is estimated that at least a total of 15,000 visitors used the 532 m trail annually.

MATERIALS AND METHODS

Location of study

Surrounded by Bukit Lagong Forest Reserve, Forest Research Institute Malaysia (FRIM) is located 16 km northwest of Kuala Lumpur. The grounds, which began as degraded land in the form of sterile mining pools, scrubby wasteland and barren vegetable farms, long-abandoned, is today a treasure of relatively unpolluted air, cooler temperatures and quiet serenity. FRIM is a popular destination for nature lovers especially because of its easy accessibility. FRIM received an average of 80,000 visitors annually where most of these are students and organized group. Being the most accessible trail and the easiest in terms of physical challenge, the Keruing Trail almost always formed a part of the itinerary of visits for FRIM visitors.

Planted seedlings

Seedlings of *Dyera costulata, Neobalanocarpus heimii, Intsia palembanica, Dryobalanops aromatica and Palaquim gutta,* were planted along the trail at 20 m intervals from centre (Figure 1). Each species was planted in a line at 1m space from the centre of the trail to a maximum of 5m. Each species was repeated at very 100 m along the trail.

Chlorophyll fluorescence measurements

Fully expanded leaves from each seedling were randomly chosen for measurements of chlorophyll fluorescence. Measurements were taken at photosynthetic photon flux density (PFD) of 1500 μmol m^{-2} s^{-1} and 70% relative humidity (RH). Leaves were darkened for 20 min by attaching light-exclusion clips to the central region of the leaf surface, avoiding the mid-vein, and chlorophyll fluorescence was measured using a plant efficient analyser (Hansatech Instruments Ltd, Kings Lynn, U.K.). Measurements were recorded up to 5 s. The fluorescence responses were induced by a red (peak at 650 nm) light of 600 Wm^{-2} intensity provided by an array of six light-emitting diodes. Previous experiments demonstrated a light intensity of 1500 μmol m^2 s^{-1} was sufficient to fully saturate leaves of all species used in this study without any photodamage (data not shown). Measurements of F_o, (Initial fluorescence) F_M, (Maximum fluorescence) and F_v (Variable fluorescence) were obtained from this procedure. F_v is derived as the difference between F_M and F_o. Fluorescence values recorded are as follows:

F_o = Minimal fluorescence.
F_m = Maximal fluorescence.
F_v/F_m = Represents the maximum quantum yield of PSII, which highly correlated with the quantum yield of net photosynthesis (Owens 1994).

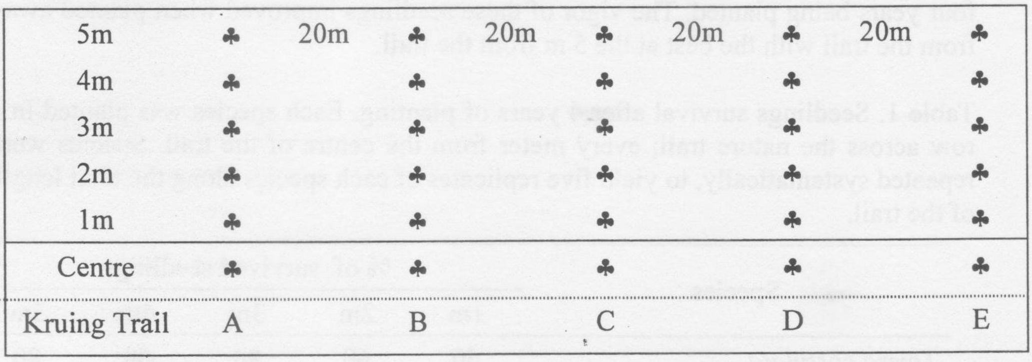

Figure 1. Experimental design of the study. Note: A, *D. aromatica;* B, *D. costulata;* C, *N. heimii;* D, *P. gutta*; E, *I. palembanica.*

Soil condition

To assess soil physical properties, penetration resistance was measured. A soil penetrologger (Eijelkemp release 3.00) was used to assess penetration resistance. A total of 20 determinations of penetrometer resistance were made in each interval at 0-15 cm depth. Measurements were taken twice between the years 2001 and 2002.

Chlorophyll contents

The chlorophyll contents were determined using a portable chlorophyll meter (SPAD-502; Minolta Co. Ltd., Japan). SPAD values are proportional to the chlorophyll concentration.

Statistical analysis

Values shown in the tables and figures are means of five replicates. Differences between means were evaluated by t-test as indicated at $p \leq 0.01$ and 0.05 levels of error using SAS Statistical package.

RESULTS AND DISCUSSION

Survival rate

The number of seedlings survived after four years of planting is shown in Table 1. Among the five species, *D. costulata* had the overall highest survival with an average of 68% while *D. aromatica* had the lowest with an average of 40% after four years being planted. The vigor of these seedlings improved when planted away from the trail with the best at the 5 m from the trail.

Table 1. Seedlings survival after 4 years of planting. Each species was planted in a row across the nature trail; every meter from the centre of the trail. Species were repeated systematically, to yield five replicates of each species along the total length of the trail.

Species	% of survived seedlings				
	1m	2m	3m	4m	5m
Dyera costulata	60	60	80	60	80
Neobalanocarpus heimii	40	60	60	60	80
Intsia palembanica	40	60	60	60	60
Dryobalanops aromatica	20	20	40	60	60
Palaquim gutta	40	50	60	60	60

The leaf colour and density of foliage of seedlings near the centre of the trail were lacking as compared with seedlings planted away from the track. Figure 3 illustrates that chlorophyll content in leaves were the lowest in seedlings closest to the trail and vice versa. Chlorophyll content was about 40 units in 1 m and 60-70 units in 4 and 5 m planting respectively.

Soil compaction

The soil compaction expressed as penetration resistance, showed that resistance decreased as the distance from the centre of the trail increased. Penetration resistance was highest between centres to 1 m (Figure 2). Soil compaction increased by 60% closest to the trail, while away from it, only a 25% increment was noted between 2001 and 2002 (Figure 2). Cass et al. (1993) reported that the upper limit for unrestricted root growth was 1MPa. Hence, the soil compaction along the Keruing Trail in FRIM could impede the growth and regeneration of seedlings.

For tropical conditions, research in Kanching Recreation Forest, Malaysia revealed that forested areas exposed to recreational use had more soil compaction compared to control areas (Kamaruzaman 1989). Noor Azlin and Philip (2003) found that soil compaction in recreational trail only occurred on the first 3 cm of soil surface.

The Keruing Trail was estimated to receive 120,000 visitors since the initiation of the study until the last data collected. The soil results indicated that the highest soil compaction increase was highest in the middle of the trail where natural distribution of trampling would be the most.

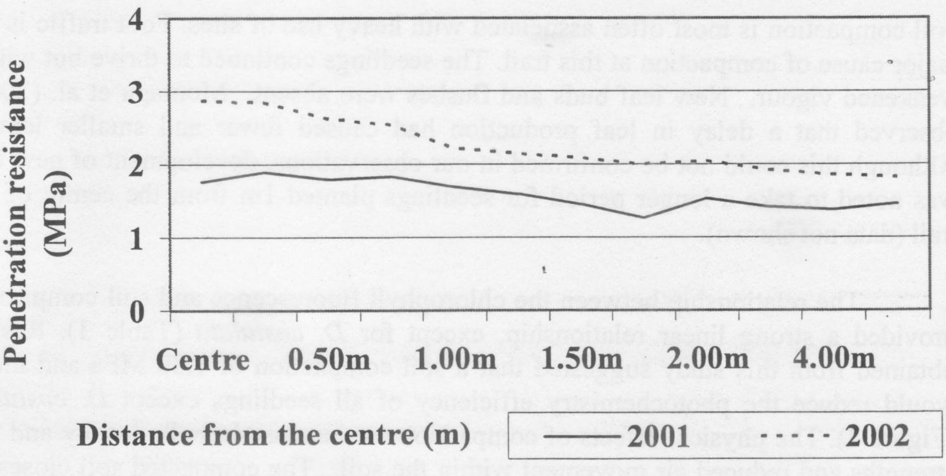

Figure 2. The soil compaction values from the centre. Each value is a mean of 20 values.

Chlorophyll fluorescence

The fluorescence readings are summarized in Table 2. The maximum quantum efficiency of PS II (F_v/F_m) readings was the lowest closer to the trail. There were no readings for seedlings planted at 1 m from the centre of trail in the final assessment because they were no fully expanded leaves except for *D. costulata and N. heimi.*

Comparing between the initial and final assessments, the F_v/F_m values were reduced especially between 1 – 2 m from the centre of the trail. F_v/F_m provides information on the energy absorbed by chlorophyll and how much is utilized and hence gives a measure of photosynthesis (Maxwell & Johnson 2000).

Table 2. The chlorophyll fluorescence measurement in percentage. Results are mean of 5 replications.

Species	1m		2m		3m		4m		5m	
	Initial	Current	Initial	Current	Initial	Current	Initial	Current	Initial	Current
Dyera costulata	80	76	75	67	81	80	84	83	83	84
Neobalanocarpus heimii	58	47	75	53	75	57	83	83	83	82
Intsia palembanica	60		70	63	73	63	83	82	86	83
Dryobalanops aromatica	53		80	61	82	61	81	76	78	79
Palaquim gutta	47		73	61	77	61	81	80	83	83

Soil compaction and seedling regeneration

Soil compaction is most often associated with heavy use of sites. Foot traffic is the major cause of compaction at this trail. The seedlings continued to thrive but with a weakened vigour. New leaf buds and flushes were absent. Montagu et al. (2001) observed that a delay in leaf production had caused fewer and smaller leaves. Although this could not be confirmed in our observations, development of new leaf was noted to take a longer period for seedlings planted 1m from the centre of the trail (data not shown).

The relationship between the chlorophyll fluorescence and soil compaction provided a strong linear relationship, except for *D. costulata* (Table 3). Results obtained from this study suggested that a soil compaction of 1.80 MPa and more, would reduce the photochemistry efficiency of all seedlings except *D. costulata* (Figure 4). The physical effects of compaction are increase in bulk density and soil strengths and reduced air movement within the soil. The compacted soil closest to the centre limited the infiltration of air and water into the root zones and affected the growth of these seedlings (Craul 1992).

From this study, it is noted that seedlings planted about 2m and beyond survived. The seedlings mortality closest to the trail could be due to poor root growth as a result of the soil compaction. Bjorkman and Deming (1987) and Johnson et al. (1993) reported that the optimal values of 83% were measured for most plant species when they are not subjected to any stress. On this accord, both *Dyera costulata* and *Intia palembanica* have the best growth rates, after 4 years assessment in most planted distance.

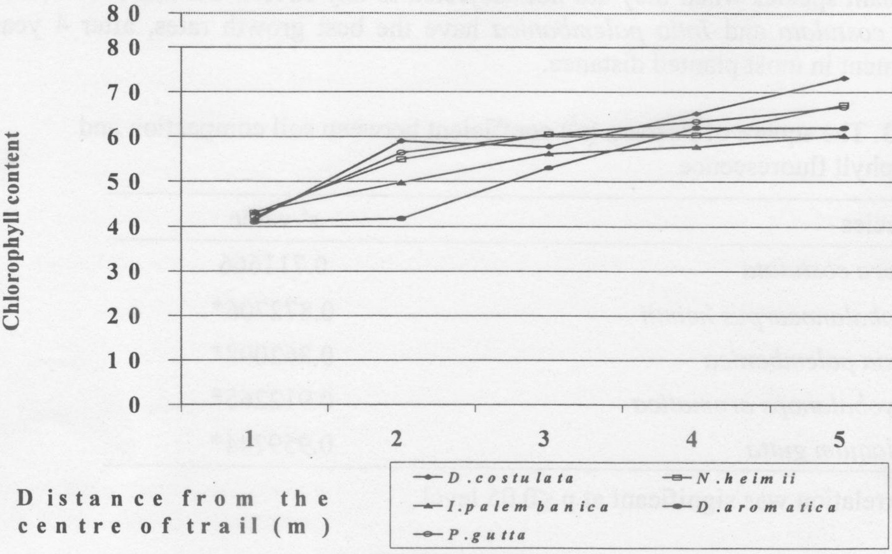

Figure 3. Leaf chlorophyll content against the distance from the centre of the trail.

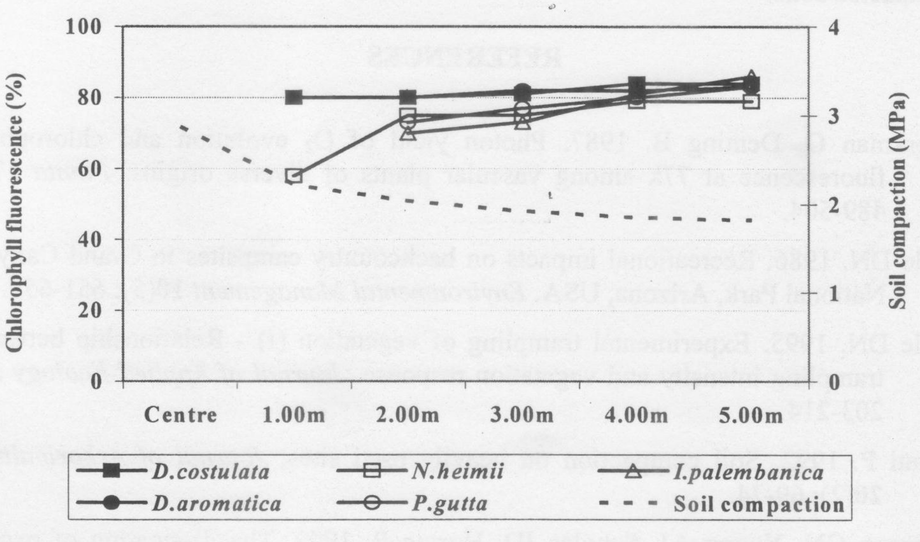

Figure 4. The relationship between chlorophyll fluorescence and soil compaction.

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Table 3. The square of Pearson (r^2) coefficient between soil compaction and chlorophyll fluorescence

Species	r^2 value
Dyera costulata	0.711666
Neobalanocarpus heimii	0.872706*
Intsia palembanica	0.862098*
Dryobalanops aromatica	0.912265*
Palaquim gutta	0.959744*

*Correlation was significant at $p \leq 0.05$ level

CONCLUSION

The poor performance of seedlings planted closest to the trail could be attributed to the poor soil condition as a result of frequent trampling. Comparing the species tested, it could be suggested that *D. aromatica* seedlings may not grow in compacted soils.

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