EFFECT OF THINNING ON THE GROWTH AND SURVIVAL OF KEORA *(SONNERATIA APETALA)*

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ABSTRACT

In order to study the necessity for thinning and a thinning schedule for keora *(Sonneratia apetala)* in the plantations, data were collected from the plots laid out in Barisal and Patuakhali coastal areas. Analysis of data indicates that mortality is generally low, more age-related than density-dependent, and that thinning will affect the survival marginally. Diameter increment decreased with increasing age and increasing density. At low densities a small enhancement of diameter increment is apparent for 5 and 6-year old plantations but this marginally exceeds the natural level of variability. Thinning may be avoided by adjustment of initial spacing—increasing it from 1.2m x 1.2m to 1.75m x 1.75m.

সারসংক্ষেপ

কেওড়া বাগানে থিনিং-এর প্রয়োজনীয়তা যাচাই এবং থিনিং পরিকল্পনা প্রণয়নের উদ্দেশ্যে বরিশাল এবং পটুয়াখালীর উপকূলীয় এলাকার নির্ধারিত প্লট হতে উপাত্ত সংগ্রহ করা হয়। উপাত্ত বিশ্লেষণে প্রতীয়মান হয় যে, গাছের মৃত্যুহার সাধারণত কম এবং ঘনত্ব অপেক্ষা বয়সের সাথে অধিক সম্পর্কিত। বেঁচে থাকার হারের উপর থিনিং এর প্রভাব নগণ্য। বয়স এবং ঘনত্ব বৃদ্ধির সাথে সাথে গাছের বেড় বৃদ্ধির হার কমতে থাকে। কম ঘনত্বে ৫ এবং ৬ বছর বয়সী বাগানে বেড় বৃদ্ধির হার সামান্য ত্বরান্বিত হয়। কিন্তু তা স্বাভাবিক বৃদ্ধির হার হতে সামান্য বেশী। প্রাথমিক রোপণ দূরত্ব পরিবর্তনের মাধ্যমে থিনিং পরিহার করা যেতে পারে। সে ক্ষেত্রে রোপণ দূরত্ব ১·২মি x ১·২মি হতে ১·৭৫মি x ১·৭৫মি বৃদ্ধি করা যেতে পারে।

INTRODUCTION

Keora, *Sonneratia apetala* is the principal species in the coastal afforestation programme, comprising appoximately 80% of the total plantations. This species will continue to be predominant over other mangrove species because of its good survival and growth on newly accreted land.

At present keora is generally planted at 1.2m X 1.2m (4´X4´) or 1.5m X 1.5m (5´x5´) spacing and within two or three years of planting out, the canopy becomes completely closed. As this species is light demanding, canopy crowding is likely to affect the growth of the trees and possibly enhance the mortality rate.

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In some plantations, first thinning has been arbitrarily undertaken after nine years although to date few experimental studies have been conducted to develop a thinning schedule for the first and the subsequent (if required) thinnings, or to standardize grades of thinning (Siddiqi 1988).

In order to (1) develop such thinning schedules, (2) to assess the yield of forest products from variously aged plantations, and (3) to determine the effects of thinning on growth and tree form, the Plantation Trial Unit of the Bangladesh Forest Research Institute has established several experimental sites at which these studies could be carried out. The analysis and interpretation of data generated from the experiments form the basis of this paper.

MATERIALS AND METHODS

Experimental design

Two experimental study areas were selected on the basis of their (1) year round accessibility and (2) on their uniformity and general 'representativeness' of existing keora plantations. The first study area was established at Rangabali (Patuakhali District) in 1987 while the second study area at Char Kukri (Barisal District) was established in 1988.

In each study area six one-acre (0.4 ha) plots were selected randomly in each of the variously aged plantations. At Rangabali, 5-, 7- and 9- year old plantations were available for study while at Char Kukri, 5- 7- and 10-year old plantations were used. Half of the plots in each age group were thinned by removing every alternate tree, while the remaining half were maintained as control plots. Thus, thinning plots were reduced in density by 50% and were comparable with similar unthinned plots.

The main effect of thinning is greater diameter growth on the remaining trees. Much research has established that height growth of trees is usually little affected by thinning (Karani 1978, Evans 1982). Therefore comparison was made on diameter increment between thinned and unthinned plots in order to observe the effect of thinnings on tree growth. Thinning caused a significant increase in diameter increment of the trees at Rangabali ($t = 3.8$; $P < 0.01$), but at Char Kukri, its effect was insignificant ($t = 1.44 < 2.034$, the tabulated value at 5% level with 34 d. f.). Moreover, as there was considerable variability in density in existing plantations, subsequent analyses for these experimental trials were not based on a comparison of thinned and unthinned plots, but rather to compare plots on a density and age basis.

The survival, diameter at 1.3 m above the ground, and the height of all trees in both treatment and control plots were measured annually from a demarcated area of 100′ x 100′ (30.5 m x 30.5 m) for each plot.

Data analysis

Two data sets are available including (1) Rangabali: 3 years from 1987 and (2) Char Kukri: 2 years from 1988. For each area, the data were combined from all 18 plots and subjected to analysis of variance (ANOVA) and regression analysis. Where the data from the two study areas showed significant statistical differences, the data were combined.

Initially, the data were examined for mortality in relation to age and plot density using multiple regression analysis. Current Annual Increment (CAI) of the diameter was then investigated against age, plot density and density classes.

RESULTS

Mortality

The per cent mortality for all plots combined at Rangabali are shown in Fig. 1 while the data for Char Kukri are given in Fig. 2.

The % mortality showed a non-significant relationship at Char Kukri and a significant ($P < 0.001$) one at Rangabali. When combined (Fig. 3), there is a significant relationship ($P < 0.001$) between % mortality and initial density with the % mortality gradually increasing up to 250 trees per plot (2690 trees ha) after which no further increase in % mortality occurs.

As the % mortality is consistent and low at both sites, the actual number of tree deaths in each plot is linearly related to the density of the plots (Fig. 4). This shows that the actual loss of trees per plots is density-dependent, attaining an annual loss of 20 trees from a plot containing 400.

The relationship between % mortality and the age of the experimental plots is statistically significant ($P < 0.01$). and shows (Fig. 5) a trend towards increasing % mortality with increasing age. Multiple regression analysis of % mortality against density and age showed that plot density accounts for a slightly larger proportion of the variance in the data than does age.

Current Annual Increment (CAI) in diameter

Simple and multiple regression analyses were initially undertaken for each data set separately to quantify the relationship between the diameter CAI and age and plot density. However, as the data from the two study areas showed no significant difference, only the analyses on the combined data are presented. The simple regressions are shown in Figs. 6 and 7.

The multiple regression equation of diameter CAI against initial plot density and age was found to be :

$$\text{Diameter CAI} = 2.463 - 0.003 \times \text{Density} - 0.085 \times \text{Age}$$

$$(F = 17.68;\ df = 2.87;\ P < 0.001)$$

In order to determine the actual diameter CAI relationship with age for various density classes, the density data for the plots were classed initially into 6 density classes on the basis of the number of trees per 30.5m x 30.5m plot. Density classes are as follows : 1) 100- 150; 2) 151—200; 3) 201—250; 4) 251 - 300, 5) 301 - 350; and 6) 351 - 400. For subsequent analysis three density classes were also used as follows : 1) 100-200; 2) 201 -300 and 3) 301-400.

These relationships are shown in Figs. 8 and 9, which may be compared with the relationships derived from the multiple regression and shown in Fig. 10.

DISCUSSION

Thinning and mortality :

On the basis of studies at Char Kukri, Siddiqi (1988) indicated that, in the absence of thinning, competition among keora plants causes increasing mortality, and hence natural thinning, with increasing age of the plantation. In a mangrove of Puerto Rico Wadsworth (1959) observed that natural mortality was dependent on the tree density in a sapling stand of white mangrove *(Laguncularia racemosa)*. However, as Fig. 5 shows, linearly increasing, or even asymptotic mortality (both as % mortality and tree deaths/plot) was observed in the experimental plots rather than the accelerating mortality found by Siddiqi (1988). More importantly, this mortality did not increase with increasing density of the experimental plots (Fig. 3) but with age suggesting that much of the mortality is age-related rather than the result of crowding or competition. In turn, this indicates that thinning (i. e. reducing the density) will only affect the likely survival marginally.

Thinning and diameter CAI :

The diameter CAI decreased in the experimental plots both with increasing age of the plantations and increasing density (Figs. 7, 8 and 9). At low densities (i. e. density class 1 and 2) a small increase is apparent for the 5- and 6-year old plots but this only marginally exceeded the natural level of variability when compared with, for example, the 10-year old plots (Figs. 8 and 9). Similarly, the graph of the diameter CAI against density classes (Fig. 11) shows that the diameter CAI of only the least dense (density class I) plots enhanced when 5- or 6-year old.

On the basis of these findings, an adjustment of densities of 1100-1600 trees/ha would result in a marginally increased diameter increment—when the plantations were 5 or 6 years old. Such an adjustment of density may be achieved either by thinning when plantations are 5 or 6 years old, or by adjusting the initial spacing so that this density is attained by natural attrition arround 5 or 6 years after planting.

Thinning and spacing :

If the products of thinning are an important outcome from the coastal plantations, and if these can be harvested economically, then it seems that the current spacing of 1.2 m x 1.2 m should be retained, with thinning carried out when the plantations are 5 or 6 years old.

However, as some doubt has been cast on the economics of thinning (Dalmacio and Bajracharya, 1989), it may be preferable to adjust the initial spacing to achieve the desired density 5 or 6 years after planting out. Based on the findings of this study and on the conclusions of the 'optimal planting season' report, this initial spacing may be determined as detailed in Table 1.

Such an initial spacing prescription reduces the initial labour involved in establishing the new plantations, but would require monitoring to ensure that unforeseen physical events, for example, have not caused major departures from the predicted survival rates. Some infilling may also still be required as mortality may occur in patches rather than randomly through newly established plantations.

Table 1 : Derivation of initial spacing for keora so as to achieve a density between 1100-1600 trees/ha at 6 years after planting out.

Year	Activity	% Survival of original seedlings	Trees/ha
0	Plant out 6-7 month old keora seedlings during June, July & August at 1.75 m x 1.75 m spacing	100	3265
1	From 'optimal planting season' report expect 60% survival after 1 year	60	1959
2	From this report expect 5% mortality per year (i. e. 60% x 0.95 = 57.0%)	57	1861
3	As above	54.1	1768
4	As above	51.4	1680
5	As above	48.8	1596
6	As above	46.4	1516

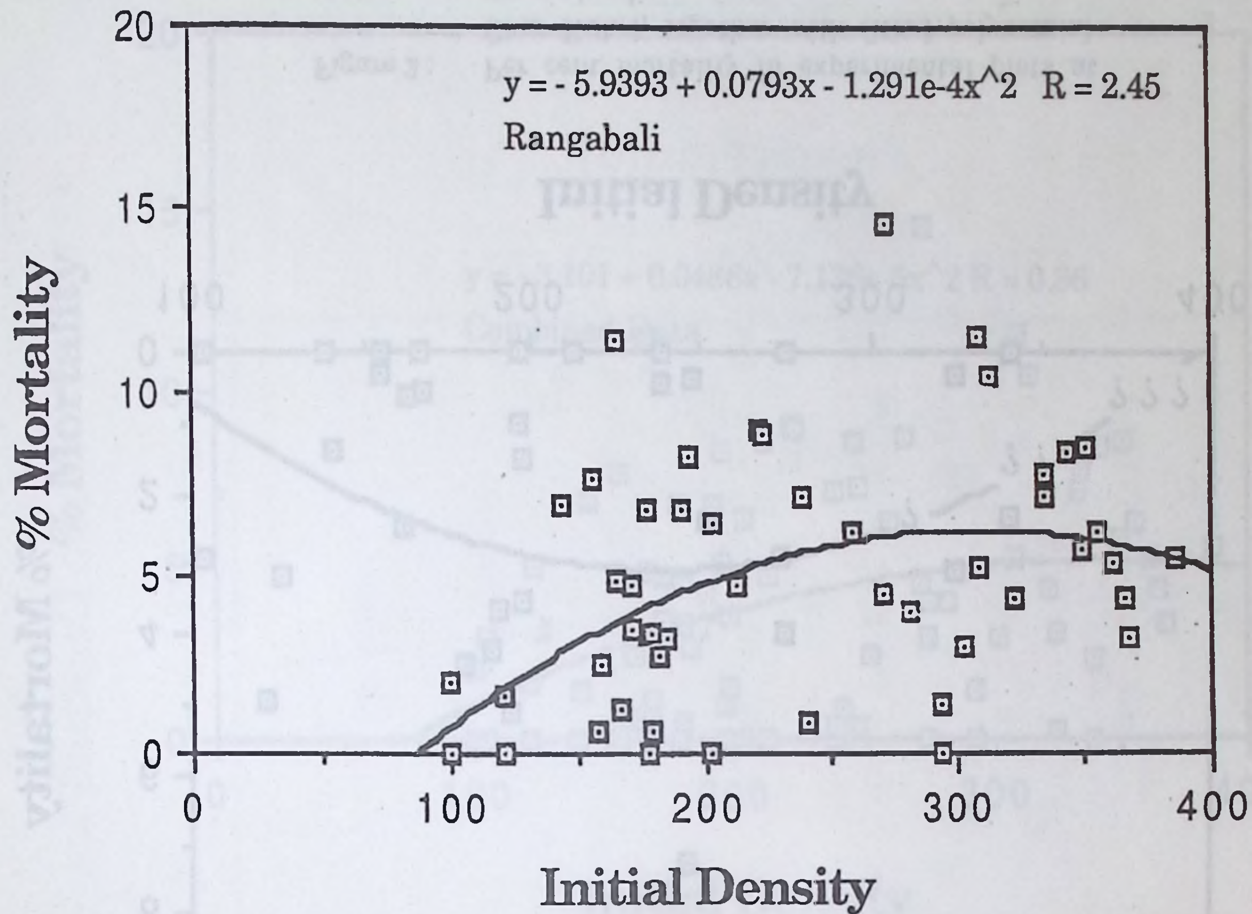

Figure 1 : Per cent mortality in experimental plots at Rangabali, together with fitted polynomial regression line.

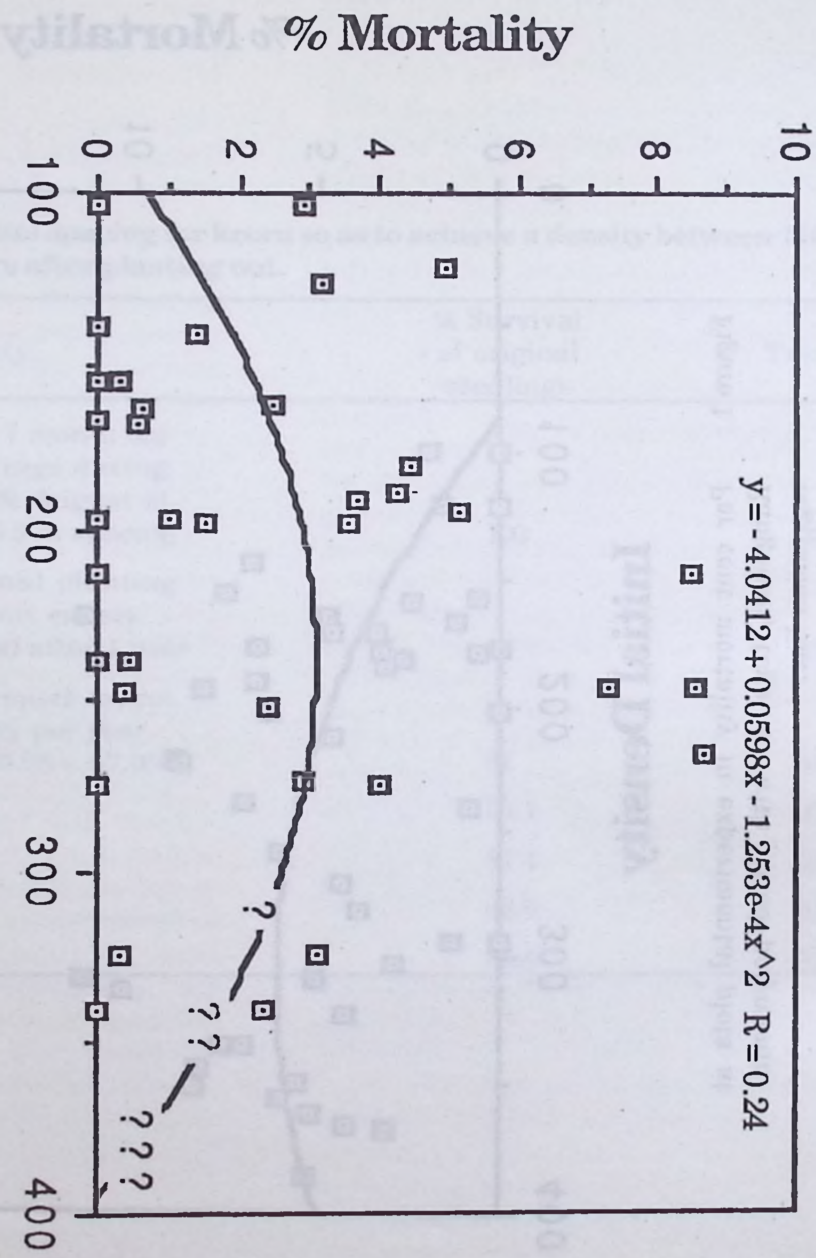

Figure 2 : Per cent mortality in experimental plots at Char Kukri, together with fitted polynomial regression line.

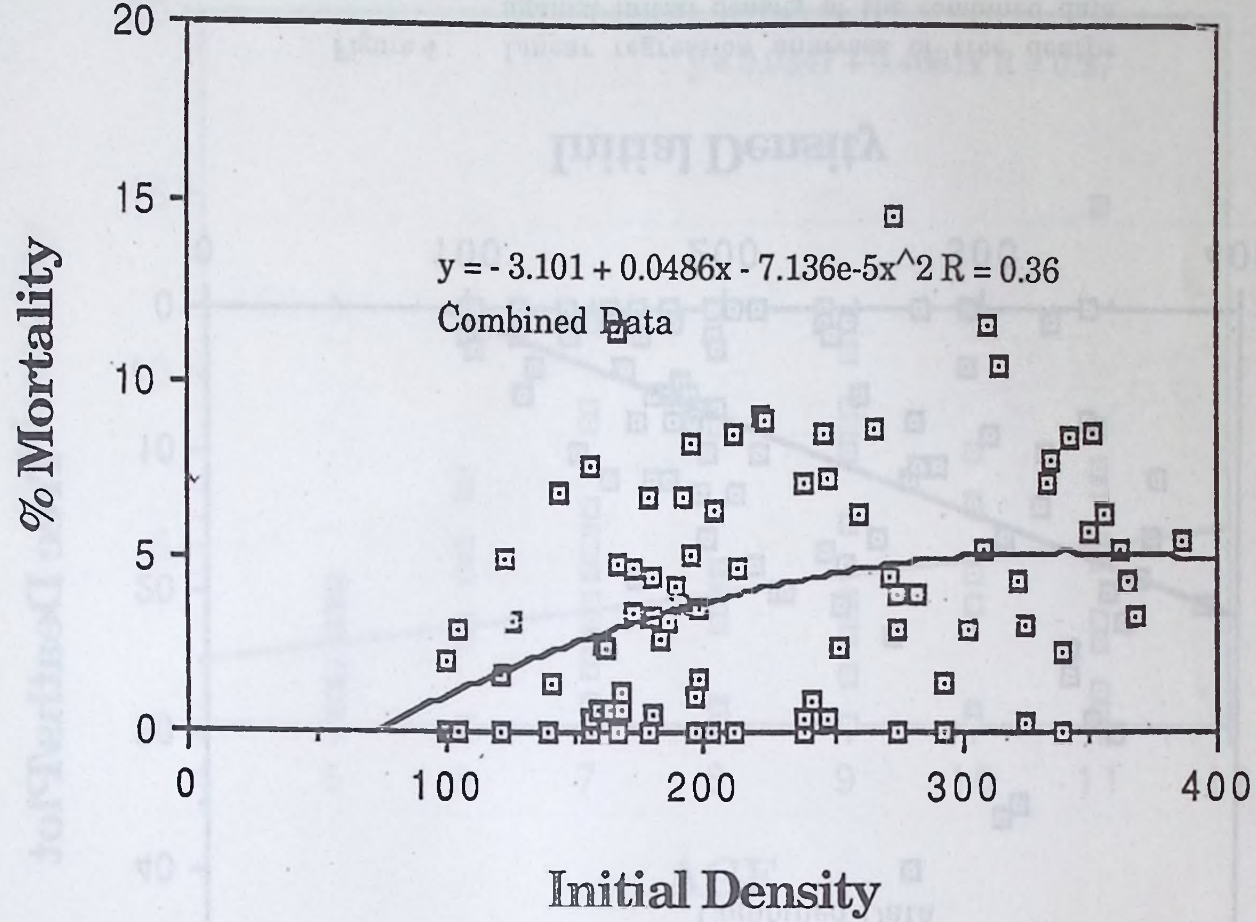

Figure 3 : Per cent mortality in combined data together with fitted polynomial regression line.

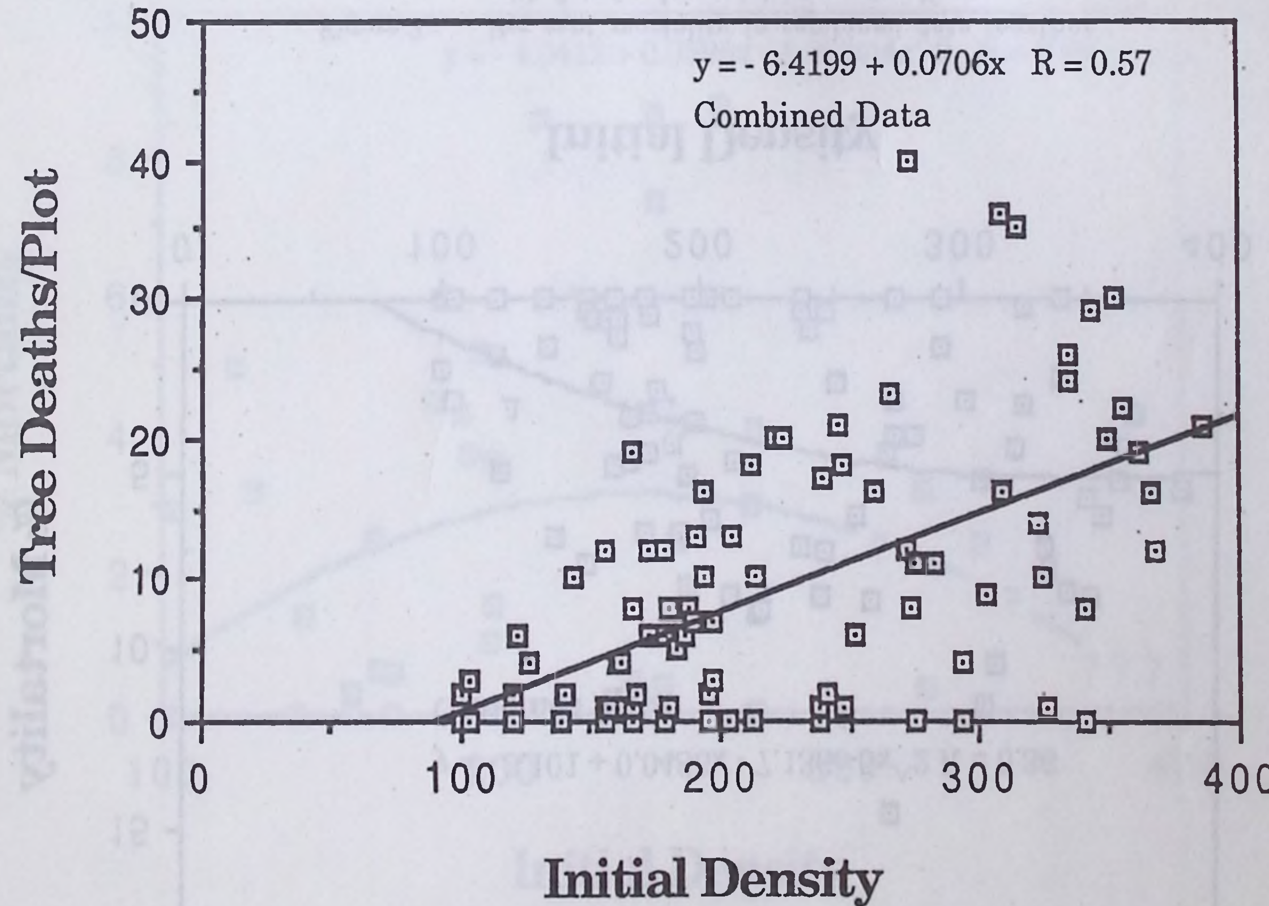

Figure 4 : Linear regression analyses of tree deaths against initial density of the combined data from Rangabali and Char Kukri.

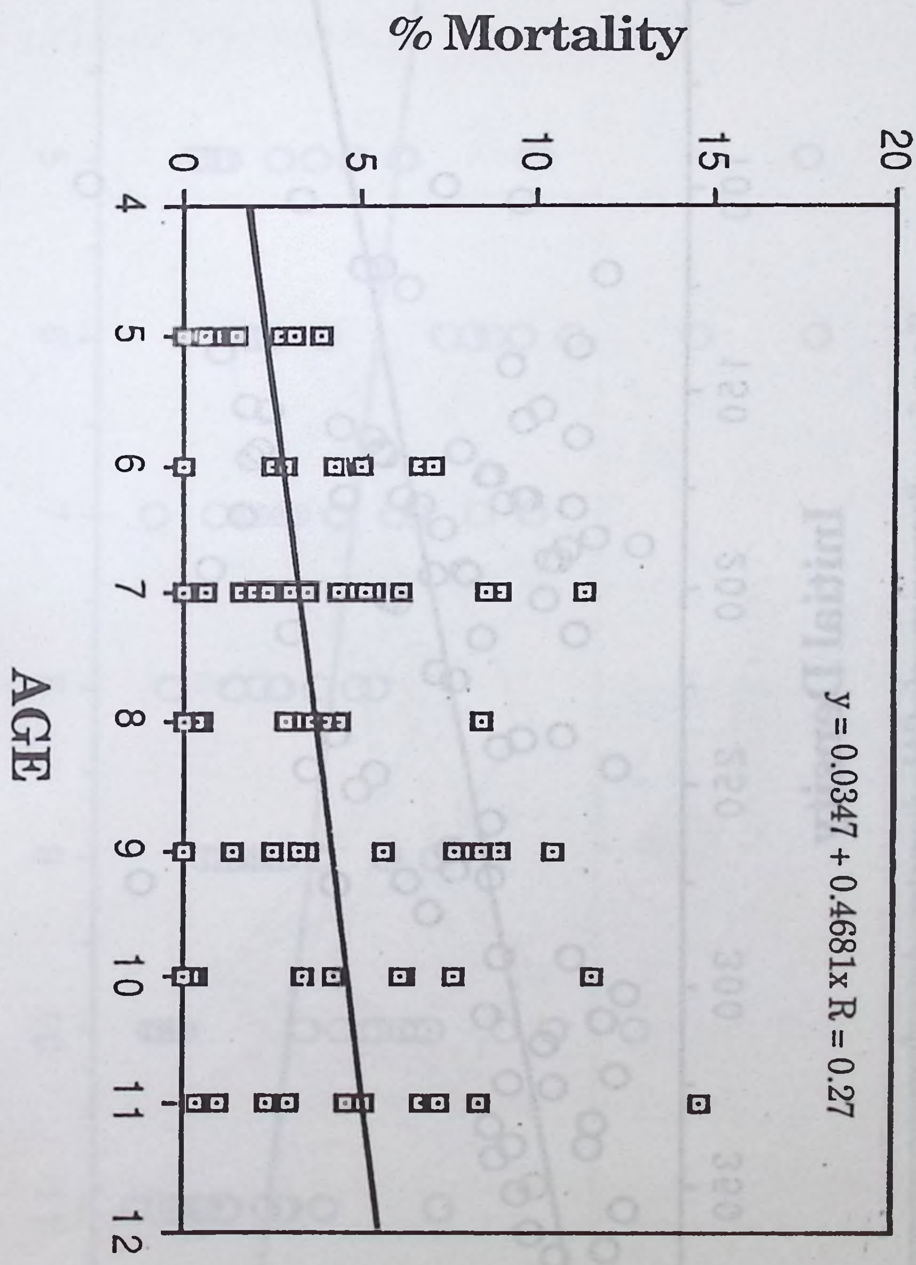

Figure 5 : Relationship between % mortality and age of the plots.

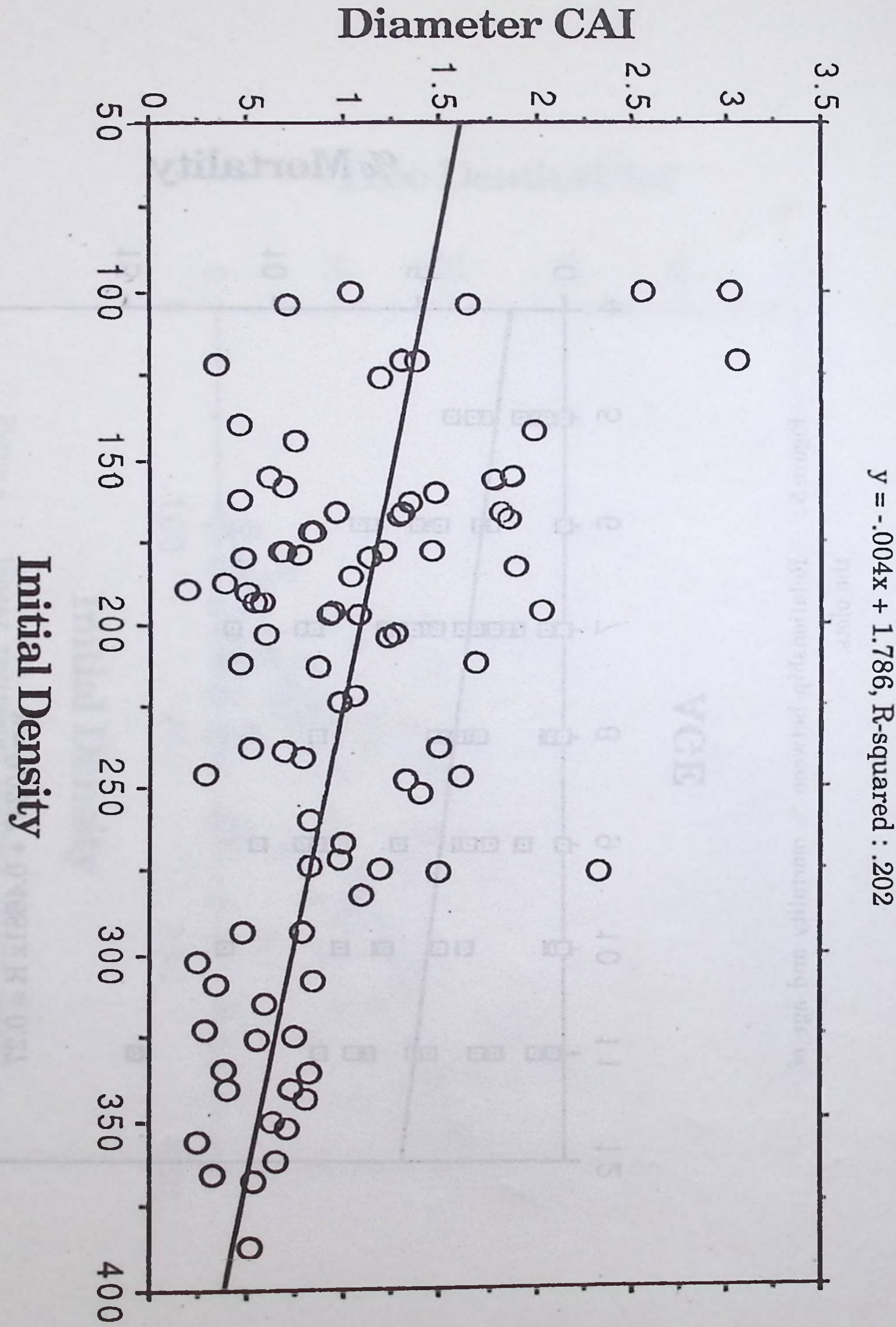

Figure 6 : Regression of CAI diameter data from Rangabali and Char Kukri against initial plot density.

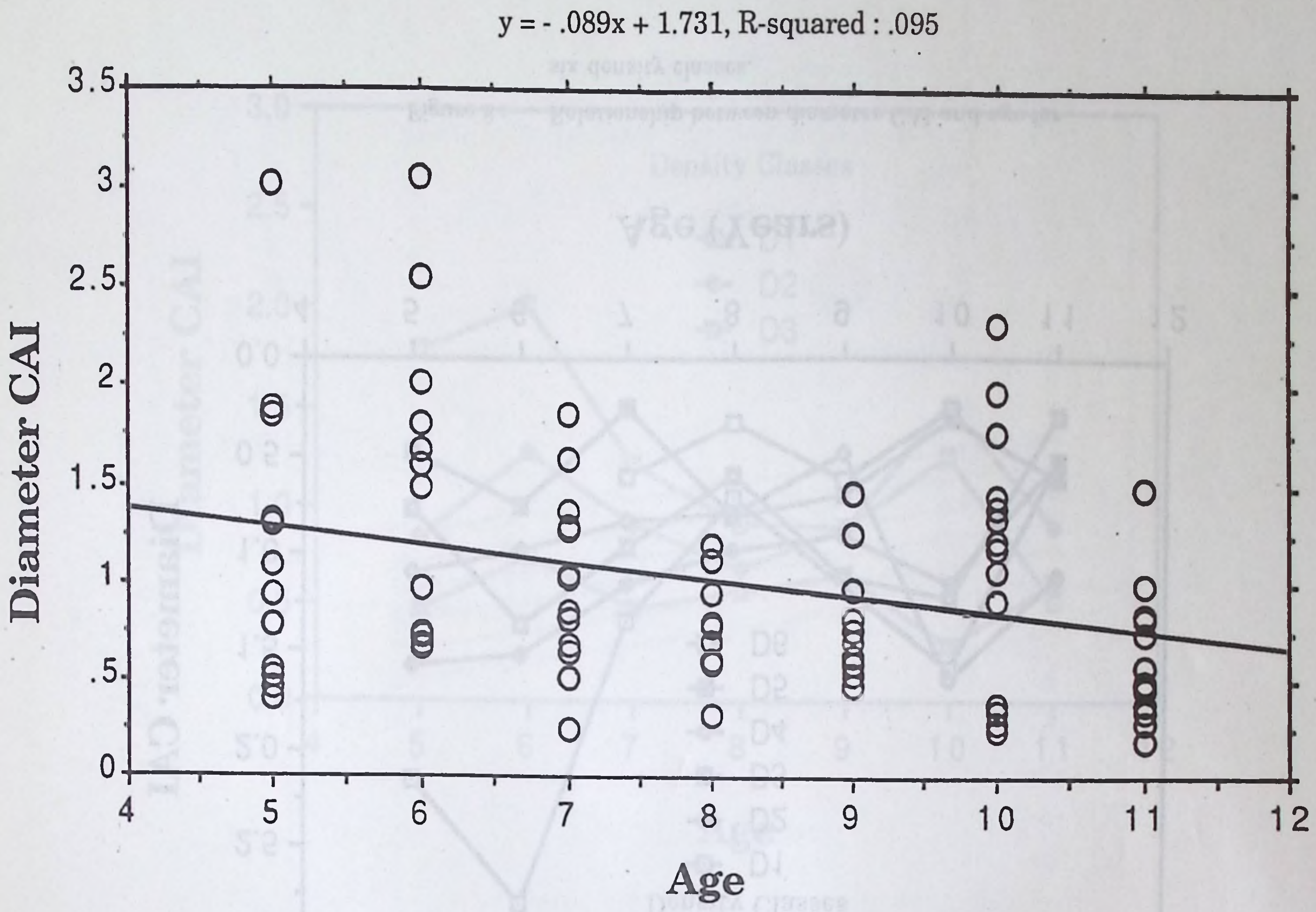

Figure 7 : Regression of CAI diameter data from Rangabali and Char Kukri against age of plots.

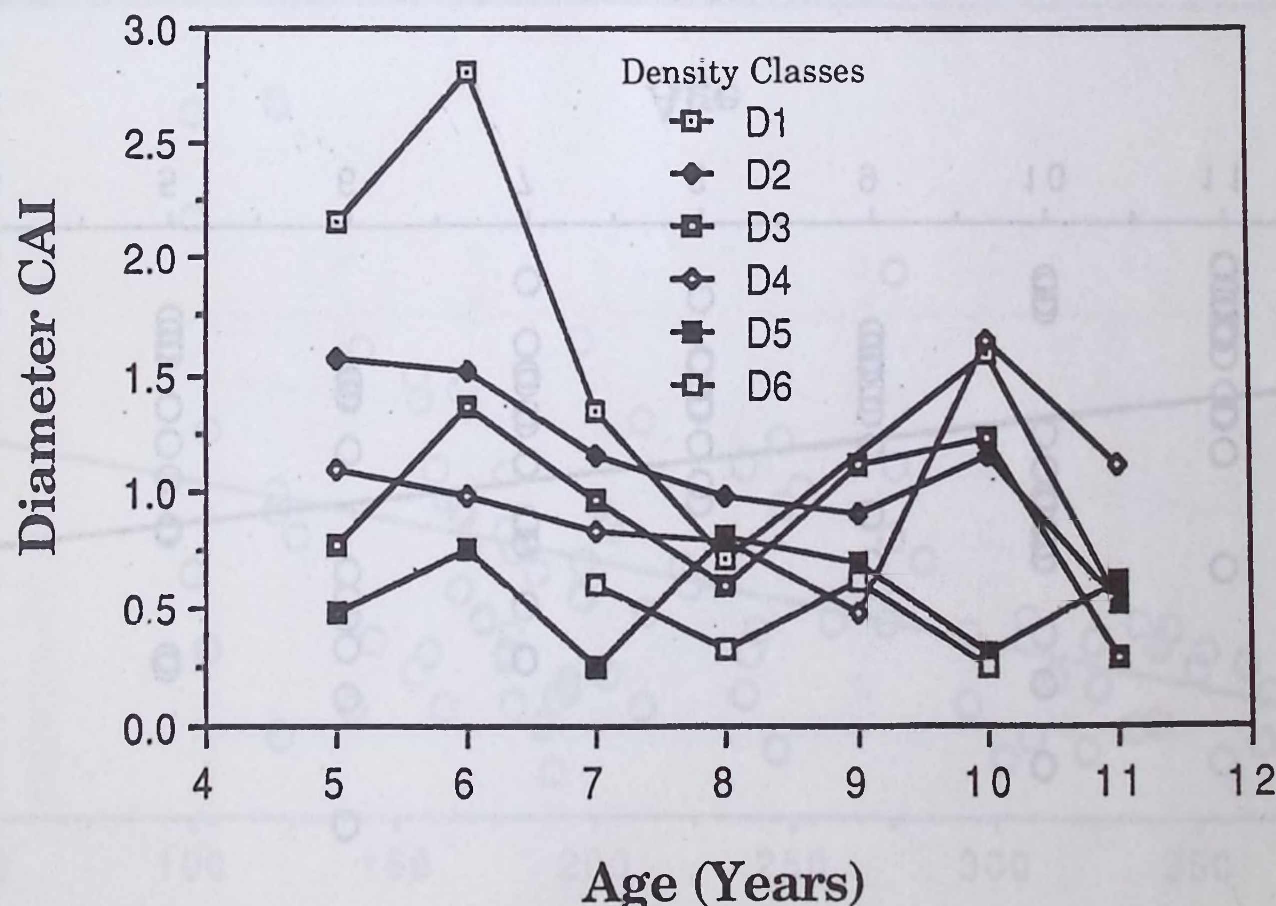

Figure 8 : Relationship between diameter CAI and age for six density classes.

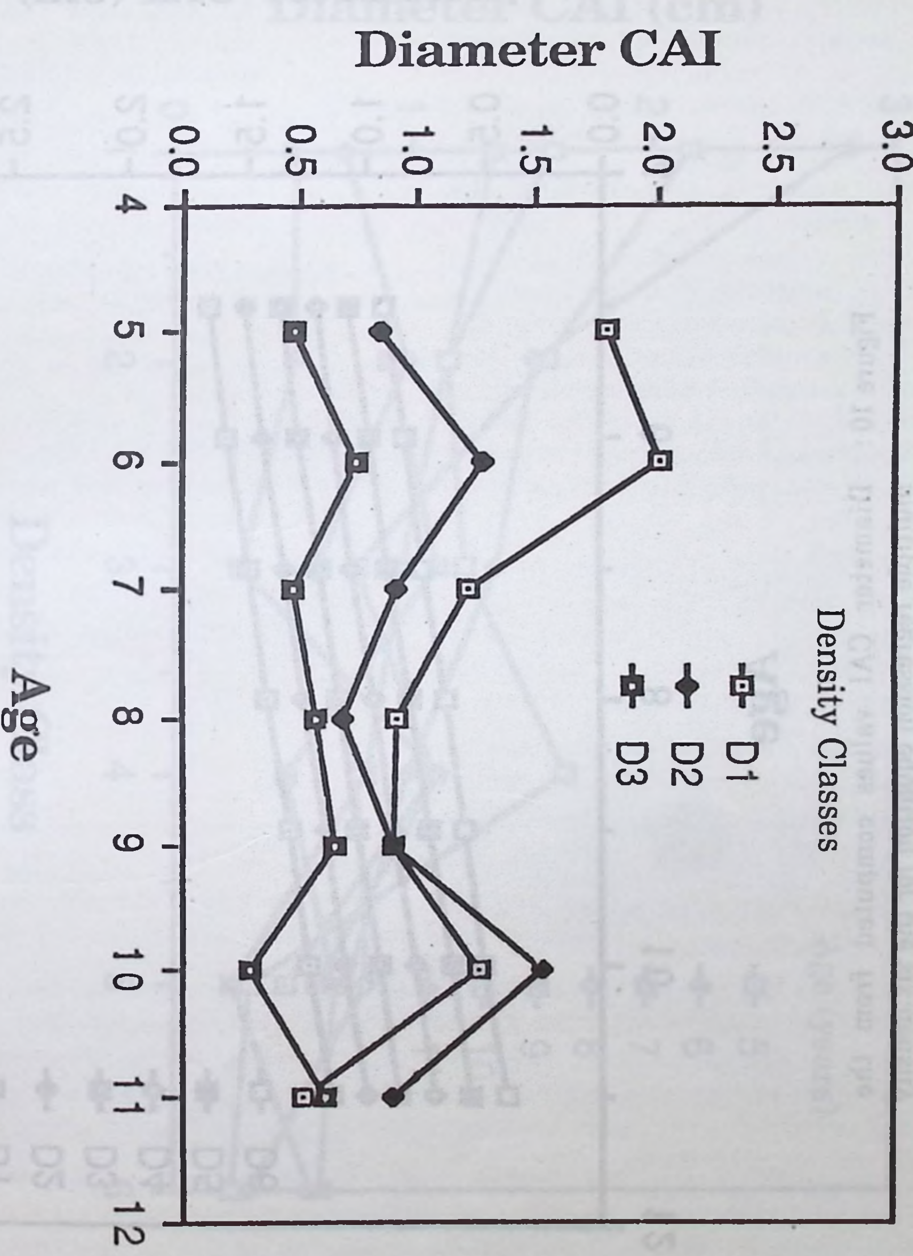

Figure 9 : Relationship between diameter CAI and age for three density classes.

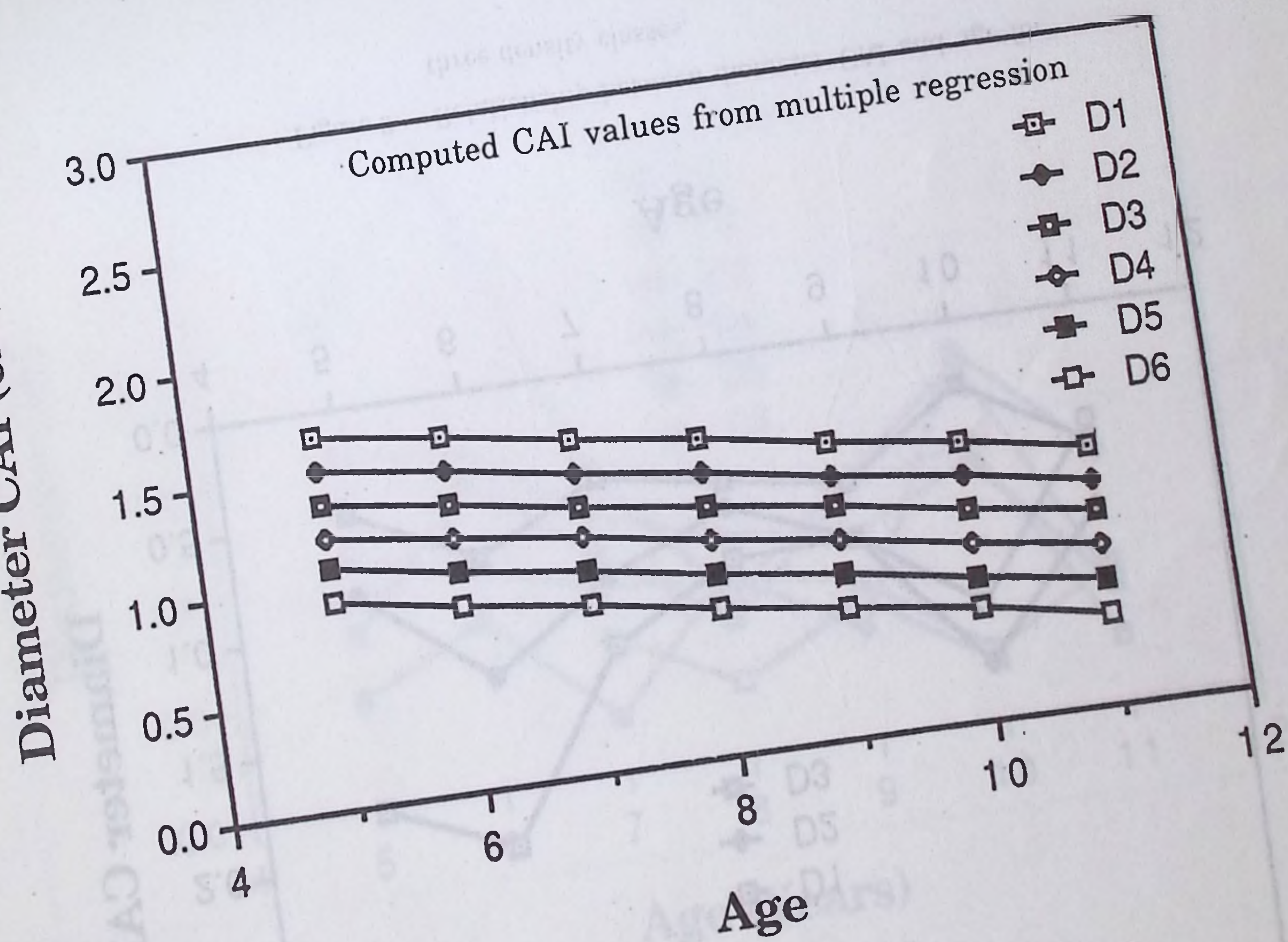

Figure 10 : Diameter CAI values computed from the multiple regression equation for the six density classes using the midpoint of each density class.

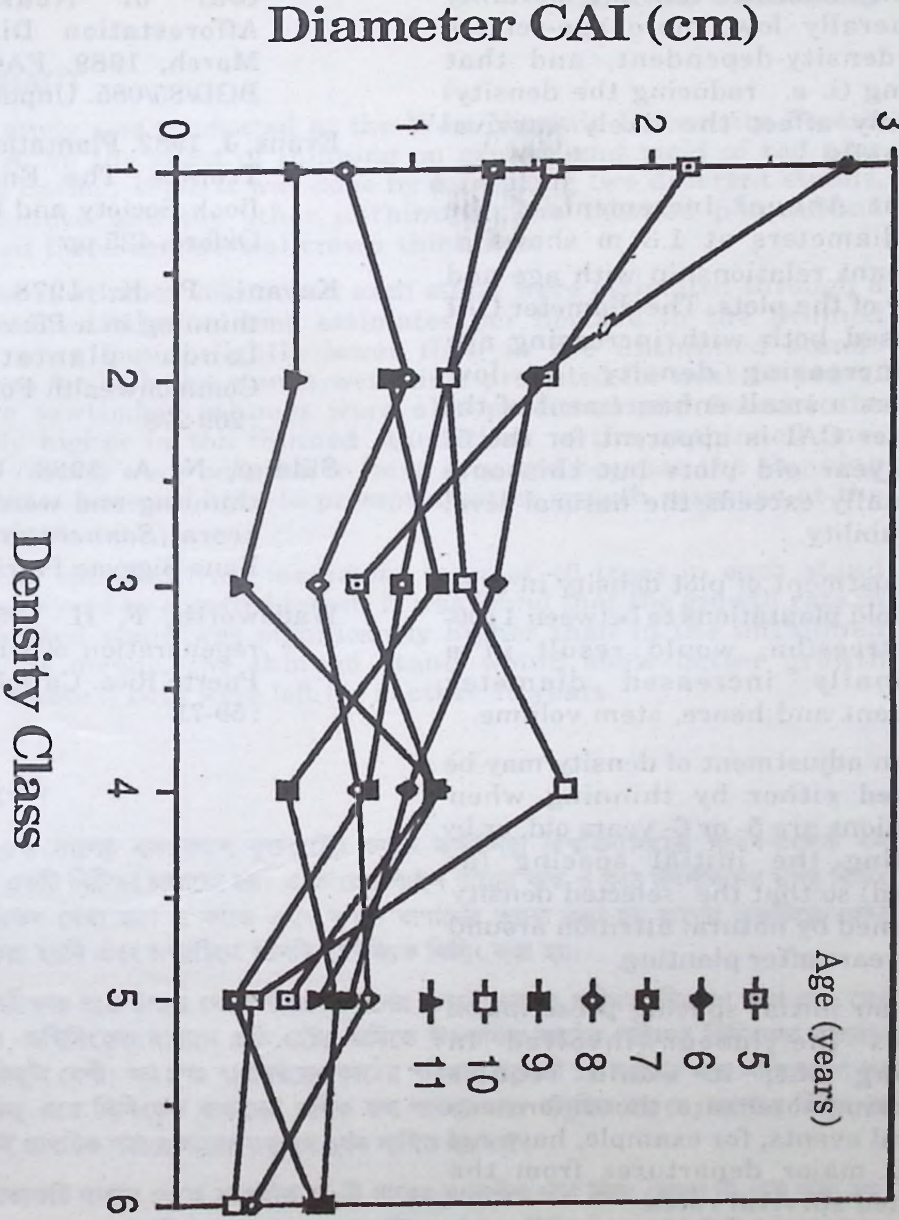

Figure 11 : Relationship between diameter CAI and six density classes for variously aged plots.

CONCLUSIONS AND RECOMMENDATIONS

1. Detailed analysis of two data-sets of mortality indicates that the mortality is generally low, more age-related than density-dependent, and that thinning (i. e. reducing the density) will only affect the likely survival marginally.

2. Current Annual Increment of the stem diameters at 1.3 m shows a significant relationship with age and density of the plots. The diameter CAI decreased both with increasing age and increasing density. At low densities a small enhancement of the diameter CAI is apparent for the 5- and 6-year old plots but this only marginally exceeds the natural level of variability.

3. An adjustment of plot density in 5- or 6-year old plantations to between 1100-1600 trees/ha, would result in a marginally increased diameter increment and hence, stem volume.

4. Such an adjustment of density may be achieved either by thinning when plantations are 5- or 6- years old, or by adjusting the initial spacing (as outlined) so that the selected density is attained by natural attrition around 5 or 6 years after planting.

5. While an initial spacing prescription reduces the labour involved in planting out, it would require monitoring to ensure the unforeseen physical events, for example, have not caused major departures from the predicted survival rates.

6. Some infilling or follow-up planting may also still be required as mortality may occur in patches rather than randomly through newly established plantations.

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