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International Journal of Current Research
Vol. 6, Issue, 09, pp.8269-8272, September, 2014

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

USE OF PILODYN FOR RAPID AND RELIABLE ESTIMATION OF WOOD BASIC DENSITY IN CLONES OF *CASUARINA EQUISETIFOLIA*

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ARTICLE INFO

Article History:
Received 15th June, 2014
Received in revised form
22nd July, 2014
Accepted 31st August, 2014
Published online 18th September, 2014

Key words:
Pilodyn, Wood Density,
Indirect Density Estimation,
Casuarina equisetifolia,
Rapid Wood Testing.

ABSTRACT

Pilodyns have been successfully used for indirect estimation of wood density in tree breeding programmes of many softwoods and hardwoods. However no reports are available on its use in clones of *Casuarina equisetifolia*. Fifty nine landrace clones of *C. equisetifolia* were subjected to Pilodyn penetration and direct wood basic density estimation at four years of age in India. Strong negative correlation was observed between Pilodyn penetration and wood basic density (-0.847). As Pilodyn observations were completed in one day, it took 8 days for the direct estimation of wood density. Mean Pilodyn readings between 4.83 and 4.05 mm; 5.45 and 5.05 mm and 8.83 and 5.65 mm indicated high density wood (0.80 to 0.86 g/cm^3), medium density wood (0.70 to 0.79 g/cm^3) and low density wood (0.46 to 0.69 g/cm^3) respectively in general. Though significant positive correlation was observed between Pilodyn penetration and moisture content, its magnitude was low (0.219). The broad sense heritability values for Pilodyn penetration and the wood basic density were moderate, 0.35 and 0.46 respectively.

INTRODUCTION

India ranks first in terms of area under *Casuarina* cultivation in the world and *Casuarina equisetifolia* is the most widely planted species of the genus in the country. Its amenability to short rotation and a sustained market demand as scaffolding in building industry, cheap housing material, banana stakes and excellent fuelwood are keys for its success (Kondas, 1983). Its nitrogen fixing ability, desirable stem form, fast growth and light crown characteristics make it an ideal tree for agroforestry systems (Viswanath *et al*., 2001). It has also gained importance as a major pulpwood species (Jain and Mohan, 2001; Nicodemus, 2004). In *C. equisetifolia* abundant phenotypic variations are reported throughout its distribution range in India. Striking phenotypic variations were observed in shape of crown, branch angle, length of branchlets, size and shape of cones and seeds. This species is reported to show tremendous variation in growth parameters also (Prasad and Dieters, 1998). Variation in wood characteristics has been observed in provenances (Varghese *et al*., 1997) and clones (Warrier *et al*., 2014) of this species. Basic density is one of the most important wood property traits, both for pulpwood and solid wood products (Raymond, 2002). In hard woods, it controls the paper making properties like burst strength, tensile strength and bulk density (Varghese *et al*., 1997). It is without doubt the single most important wood property because of its strong relationship to both yield and quality as well as its large variance and high heritability (Zobel and Jett, 1995). Wood density is a trait of interest for incorporation into tree breeding programmes as it is under moderate to strong genetic control (Raymond, 1995; Kennedy *et al*., 2013).

The most commonly used method for estimation of wood properties is from discs extracted from trees and it is essential to sample large number of trees for precise estimations. This destructive testing leads to a conflict between the need to preserve valuable genetic material and the need to gain information on various wood properties (Varghese *et al*., 1997). Though assessment of density could be achieved through a non destructive method of increment core samples (Greaves *et al*., 1996), it is quite cumbersome when used manually. Pilodyn is a hand held instrument originally developed to assess the degree of soft rot in transmission poles (Booker, 1983). It fires a flat nosed pin into a tree with a fixed force. The depth of penetration of the pin can be read directly from the scale on the top of the instrument. This instrument can be successfully used for estimating the wood density of standing trees indirectly as the depth of penetration of the pin is strongly negatively correlated with wood basic density at the point of sampling (Greaves *et al*., 1996; Raymond and MacDonald, 1998; YingChun *et al*., 2010; Humar and Thaler, 2013). Pylodins have been used for rapid, non-destructive assessment of density in tree breeding programmes of softwoods (King *et al*., 1998; QiFu *et al*., 2011) and hardwoods (MacDonald *et al*., 1997; Raymond and MacDonald, 1998; YaFang *et al*., 2008). Among the hardwoods, the genus

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Eucalyptus has been widely subjected to indirect wood density estimation using Pilodyn. Pilodyn studies in casuarinas are limited. Therefore, an attempt was made to understand the relationship between Pilodyn penetration and wood density in select clones of *Casuarina equisetifolia*.

MATERIALS AND METHODS

The experimental materials comprised of 59 landrace clones of *Casuarina equisetifolia* grown in a clonal trial at Tiruchirapalli district (10° 45' N latitude and 78° 36' E longitude at an altitude of 85 m above MSL) in Tamil Nadu, India by the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore. The experiment was laid out in a Randomized Complete Block Design with four replications at spacing of 2m x 2m. These clones were originally selected from Chengalpet (Latitude 12° 42' N, Longitude 80° 01' E) Chidambaram (Latitude 11° 24' N, Longitude 79° 44' E) and Tiruchendur (Latitude 8° 30' N, Longitude 78° 11' E) in Tamil Nadu (Kumar and Gurumurthi, 1996; Balasubramanian, 2000). The equipment used for indirect density assessment was a 6J Pilodyn (6 joules of energy supplied to the pin by the spring) with a 2.5 mm striker pin. Two Pilodyn shots (one in the south and one in the east part of the stem at 1.37 m from the ground level, averaged) were taken on each tree in four replications, according to method described by Hansen (2000). A small section of the bark was removed prior to taking the Pilodyn reading. Wood discs were extracted following the Pilodyn measurements at 1.37 m from the ground level for direct wood density measurements. Green volume of each disc sample was determined by water displacement method (Oleson, 1971). Weight of water displaced by immersion of disc indicated fresh volume of the sample and the samples were dried in hot air oven for 96 hours at 100°C to obtain the oven dry weight. Basic density of each sample was determined by using the formula

Basic density=Oven dry weight (g) / Green volume (cm^3)

The method of water displacement is considered as one of the most precise method, especially when working with small samples (Valencia and Vargas, 1997). Both the direct and indirect methods of wood density estimation were undertaken at 4 years of age. The data were statistically analysed for ANOVA. Correlations among the wood characteristics were also determined.

RESULTS AND DISCUSSION

Significant differences at 5 per cent level were observed among the 59 clones of *Casuarina equisetifolia* with respect to Pilodyn penetration, wood basic density and moisture content (Table 1). The mean values for Pilodyn penetration ranged from 4.05 mm to 8.83 mm with a mean of 5.06 mm (±0.97 mm SD). Wood basic density of these clones varied from 0.46 g/cm³ to 0.87 g/cm³. The mean and standard deviation were 0.76 and 0.07 respectively. Variation observed for moisture content was between 30.71% and 57.38% (47.92 ± 5.79).

Table 1. Mean pilodyn penetration, wood density and moisture content in clones of *Casuarina equisetifolia*

Clone No	Pilodyn Penetration (mm)*	Wood Density (g/cm³)*	Moisture Content (%)*
1	4.40 f-k	0.84 a-c	46.11 e-p
2	4.98 c-k	0.76 c-o	47.50 c-p
3	5.08 c-k	0.77 b-n	48.05 c-p
4	4.28 i-k	0.83 a-d	51.63 a-j
5	4.63 d-k	0.78 a-l	42.38 op
6	4.40 f-k	0.84 ab	30.71 q
7	6.80 b	0.59 p	46.43 d-p
8	4.33 g-k	0.82 a-h	44.72 i-p
9	5.28 c-k	0.75 e-o	48.07 c-p
10	5.23 c-k	0.72 j-o	53.05 a-g
11	4.40 f-k	0.78 a-l	51.24 a-j
12	5.10 c-k	0.75 g-o	53.86 a-e
13	4.75 d-k	0.79 a-l	46.70 c-p
14	4.63 d-k	0.77 b-n	46.71 c-p
15	5.78 b-d	0.73 i-o	42.81 m-p
16	4.53 d-k	0.78 b-m	54.15 a-d
17	4.65 d-k	0.80 a-k	40.88 p
18	4.83 c-k	0.75 e-o	46.10 e-p
19	5.58 c-h	0.72 i-o	50.58 a-m
20	5.73 b-d	0.71 l-o	55.96 ab
21	4.35 g-k	0.83 a-e	42.71 n-p
22	4.65 d-k	0.76 d-o	46.24 e-p
23	4.63 d-k	0.77 b-n	45.47 g-p
24	4.13 jk	0.82 a-h	45.87 f-p
25	5.65 b-f	0.69 no	46.84 c-p
26	4.53 d-k	0.77 b-m	53.44 a-f
27	5.28 c-k	0.75 g-o	53.39 a-f
28	4.88 c-k	0.78 b-m	45.30 g-p
29	5.30 c-k	0.74 g-o	51.17 a-k
30	4.05 k	0.83 a-f	48.87 b-o
31	4.30 h-k	0.79 a-l	48.80 b-o
32	4.73 d-k	0.77 b-m	46.56 c-p
33	8.83 a	0.46 q	43.97 j-p
34	5.15 c-k	0.74 h-o	51.49 a-j
35	4.30 h-k	0.82 a-g	49.40 b-o
36	4.28 i-k	0.80 a-j	46.91 c-p
37	4.75 d-k	0.75 f-o	50.45 a-n
38	4.93 c-k	0.74 g-o	47.30 c-p
39	5.33 c-k	0.73 i-o	57.38 a
40	5.48 c-i	0.72 k-o	52.76 a-h
41	5.70 b-e	0.75 f-o	50.56 a-m
42	5.60 c-g	0.74 g-o	50.89 a-l
43	4.65 d-k	0.82 a-g	44.13 i-p
44	4.83 c-k	0.80 a-j	47.65 c-p
45	5.73 b-d	0.77 b-m	48.52 b-p
46	5.05 c-k	0.79 a-l	42.48 op
47	5.23 c-k	0.75 f-o	54.32 a-c
48	5.50 c-i	0.75 g-o	51.81 a-i
49	5.65 b-f	0.78 b-m	49.04 b-o
50	4.78 c-k	0.80 a-i	46.03 f-p
51	5.15 c-k	0.73 i-o	53.35 a-f
52	5.40 c-j	0.73 i-o	48.15 c-p
53	5.45 c-i	0.70 m-o	46.04 f-p
54	4.43 e-k	0.86 a	42.46 op
55	4.70 d-k	0.78 b-m	43.21 l-p
56	5.25 c-k	0.75 e-o	49.00 b-o
57	5.28 c-k	0.78 b-m	43.42 k-p
58	5.18 c-k	0.76 d-o	45.09 h-p
59	6.05 bc	0.69 o	49.30 b-o
Mean	5.06	0.76	47.92
SD	0.97	0.07	5.79
SEM	0.06	0.01	0.38

Means with the same letter in a column do not differ significantly as per Duncan's Multiple Range Test at 5% level of significance.
* Significant at 5%

Results of correlations among the three characters are given in Table 2. Strong negative correlation was observed between Pilodyn penetration and wood basic density (-0.847).

Table 2. Correlation matrix for pilodyn penetration, wood density and moisture content in clones of *Casuarina equisetifolia*

	Pilodyn Penetration (mm)	Wood Density (g/cm^3)	Moisture Content (%)
Pilodyn Penetration (mm)	1.000	-0.847**	0.219*
Wood Density (g/cm^3)		1.000	-0.347*
Moisture Content (%)			1.000

* Significant at 5% ** Significant at 1%

Table 3. Regression statistics

Title of X Variable	Pilodyn Readings	
Title of Y Variable	Wood Basic Density	
Number of Data Points	(K):	236
Mean of X Variable	(X-bar):	5.057
Mean of Y Variable	(Y-bar):	0.759
Variance of X Variable		0.935
Variance of Y Variable		0.005
Coefficient of Correlation	(r):	-0.847
Regression Line Intercept	(a):	1.079
Regression Line Slope	(b):	-0.063
Standard Error of Slope	(s):	0.003
t Test Value	(t):	24.347
Probability	(P):	<0.001

The regression statistics are given in Table 3. Kien *et al*. (2008) reported a genetic correlation (-0.86) between Pilodyn penetration and wood density and suggested that Pilodyn could be used reliably as an indirect measurement of wood basic density in *Eucalyptus urophylla*. Strong negative relationships were found for Pilodyn and wood density in *Pinus elliottii* and the use of Pilodyn allowed the detection of families or groups of trees with high, medium or low wood density (Lopez and Staffieri, 2004). As Pilodyn observations were completed in one day, it took 8 days for the direct estimation of wood density. Pilodyn sampling is faster, cheaper, and not destructive, thus resulting in overall higher expected gains for selection of trees or culling of seedling seed orchards in comparison with the more destructive direct assessment of density (QiFu *et al.,* 2011). Fukatsu *et al.* (2011) studied the efficiency of the indirect selection using Pilodyn for the genetic improvement of wood density in *Cryptomeria japonica* and reported that indirect selection using the Pilodyn realized 87% of the genetic gain obtained by the direct selection of wood density. The Pilodyn penetration depth was highly correlated with wood density, and the genetic correlation between them was -0.88. In the present study, the broad sense heritability values for Pilodyn penetration and the wood basic density were 0.35 and 0.46 respectively. Hidayati *et al.* (2013) reported moderate values for Pilodyn penetration and wood properties in *Tectona grandis*. Heritability estimates in this study for Pilodyn penetration was lower than that of direct density estimation. Similar result has been reported in *Eucalyptus urophylla* (Wei and Borralho, 1997; Kien *et al.,* 2008). The lower heritability estimated for Pilodyn penetration compared to that of direct density estimation suggested that selection for wood basic density based on Pilodyn penetration would not give as high genetic gain as selection based on direct measurement of wood density.

Though significant positive correlation was observed (Table 2) between Pilodyn penetration and moisture content, its magnitude was low (0.219). Chapola (1994) also had noticed correlation between green moisture content and Pilodyn readings in *Eucalyptus*. Determination of wood basic density shall help in identifying end use specific materials in multipurpose species like *Casuarina equisetifolia*. It is generally used for poles, scaffoldings or pulp. Therefore, clones with high dense wood could be utilized for poles or scaffoldings whereas medium and low density wood may be suitable for pulp wood production. In the present study, mean Pilodyn readings between 4.83 and 4.05 mm; 5.45 and 5.05 mm and 8.83 and 5.65 mm indicated high density wood (0.80 to 0.86 g/cm^3), medium density wood (0.70 to 0.79 g/cm^3) and low density wood (0.46 to 0.69 g/cm^3) respectively in general. The study indicated that Pilodyn could be effectively used for rapid and reliable indirect estimation of wood density in *C. equisetifolia*.

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