Assessing the Performance and Adaptability of International Provenances of *Casuarina equisetifolia* Grown in India

Abstract

A special concern in tree improvement and genetic testing relates to genotype x environment interaction which means that the relative performance of clones, families, provenances or species differs when they are grown in different environments. In tree improvement, superior performing genotypes in a range of environments are highly desired. Though stability analyses have widely been conducted in agricultural crops, only limited studies have been reported in tree species. An experiment through multi-location field testing was conducted at the ICFRE-Institute of Forest Genetics and Tree Breeding, Coimbatore, India to study the stability of select international provenances of *Casuarina equisetifolia* L. Seedlings raised from 23 international provenances infused from CSIRO, Australia formed the basic experimental materials and multilocational provenance trials were established in five locations in India. All the provenance trials were established in Randomized Complete Block Design with five replications and with 10 tree plots. Stability analysis was performed using the data on tree height, diameter at breast height (dbh) and volume index (d^2h) recorded at 3 years of age. The analysis was carried out following the method suggested by Eberhart and Russel. Provenances, 18144 Kenya, 18160 Malaysia, 18298 Thailand, 18355 Benin, 18268 China, Palacherla A India and Mixed Seedlot India 5 were included in group I when stability parameters for tree height was considered and hence are the most stable clones with respect to tree height. 18298 Thailand and 18586 China though recorded high mean values, were found unpredictable over growth periods due to the significant deviation from regression. Four provenances namely, 18160 Malaysia, 18357 Philippines, 18268 China and Palacherla A India exhibited stability for DBH. Five provenances, 18144 Kenya, 18160 Malaysia, 18355 Benin, 18268 China and Palacherla A proved to be stable across the five locations with respect to volume index. No provenances were found suitable for planting in sites with stress or favourable conditions.

Key word: Planting , Conditions, Casuarina Equisetifolia, Tree Species

1.0 Introduction

"Casuarinas are widely planted in the tropics, subtropics and Mediterranean countries because of their ready adaptability to a variety of environmental conditions and also for their rapid growth performance. In barren areas where majority of the plant species do not grow, Casuarina spp. thrive and turn them productive" [1]. "Among the 96 species of trees and shrubs in the family Casuarinaceae, *Casuarina equisetifolia* has gained much attention due to its multiple end-uses". [2] This species also known as "Australian Pine" is now one of the most common trees on the frost-free beaches anywhere in the world.

"In India, *C. equisetifolia* was introduced from Australia in the second half of nineteenth century mainly to fuel the steam locomotives. It was originally planted in Karwar during 1868-69 [3], Nilgiris of the then Madras Presidency [4], and Chengalpet and South Arcot districts of Tamil Nadu state" [5]. "The species later spread along the coasts to different parts of Tamil Nadu, Andhra Pradesh, Odisha and West Bengal. It was also introduced in the coastal areas of Kerala, Maharashtra and Karnataka. India is the largest Casuarina growing country in the world with an estimated 800,000 ha of plantations" [6,7]. "Casuarina based farming is very popular in the coastal regions of peninsular India as it buffers the economy against crop failure and drought. It has also gained importance as a major pulpwood species" [8]. "Its usefulness in environmental protection has been fully realized after the tsunami and is now a major component in any coastal afforestation programme in India" [9].

"A special concern in tree improvement and genetic testing relates to genotype x environment interaction which means that the relative performance of clones, families, provenances or species differs when they are grown in different environments. Because of the possible presence of G x E interaction, it is always advisable that genetic tests be established in multiple environments" [10]. "In tree improvement, superior performing genotypes in a range of environments are highly desired" [11,12]. "Though stability analyses have widely been conducted in agricultural crops, only limited studies have been reported in tree species". [11,12]

An experiment through multi-location field testing was conducted at the ICFRE-Institute of Forest Genetics and Tree Breeding, Coimbatore, India to study the stability of select international provenances of *C. equisetifolia*.

2.0 Materials and Methods

Seedlings raised from 23 international provenances infused from CSIRO, Australia formed the basic experimental materials. Multilocational provenance trials were established in five locations in India namely, Marimalai Nagar, near Chennai, Tamil Nadu (Latitude: 12°47'34.83" N and Longitude: 80°01'30.86" E, Altitude 55 m), Neyveli, Tamil Nadu (Latitude: 11°32'20.33" N and Longitude: 79°28'45.79" E, Altitude 35 m), Thuvarankurichy, Tamil Nadu (Latitude: 10°22'43.77" N and Longitude: 78°23'15.64"' E, Altitude 70 m), Narasipatnam, Andhra Pradesh (Latitude: 17°39'59.16" N and Longitude: 82°36'37.88" E, Altitude 80 m) and Rayagada, Odisha (Latitude: 19°10'15.81" N and Longitude: 83°24'58.47" E, Altitude 219 m).

All the provenance trials were established in Randomized Complete Block Design with five replications and with 10 tree plots. The spacing adopted was 2m x 2m.

Table 1. List of select international provenances of *C. equisetifolia*.

Sl No	Provenance No	Country
1	17577	PNG
2	18008	NT AUSTRALIA
3	18122	EGYPT
4	18128	VIETNAM
5	18134	KENYA
6	18135	KENYA
7	18137	KENYA
8	18141	KENYA
9	18144	KENYA
10	18160	MALAYSIA
11	18267	CHINA
12	18297	THAILAND
13	18298	THAILAND
14	18344	MALAYSIA
15	18378	QLD
16	18153	PNG
17	18357	PHILIPPINES
18	18136	KENYA
19	18586	CHINA
20	18355	BENIN
21	18268	CHINA
22	PALACHERLA A	INDIA
23	MIXED SEEDLOT	INDIA

"Stability analysis was performed using the data on tree height, diameter at breast height (dbh) and volume index (d^2h) recorded at 3 years of age. The analysis was carried out following the method suggested by Eberhart and Russel (1966)" [13].

Considering Yij as the mean observation of ith provenance in jth environment, the stability model described by them is as follows

$Y_{ij} = m + B_i I_j + \delta_{ij}$ (i = 1,2……t and j = 1,2, …..s)

(t = provenances; s = environments)

where,

Yij = Mean of ith provenance in jth environment.

m = Mean of all the provenances.

bi = Regression coefficient of the ith provenance on the environmental index which measures the response of the provenance to varying environments.

ij = The environmental index which is defined as the deviation of the mean of all the provenances in jth environment from the overall mean.

$$= \frac{\sum_i Y_{ij}}{t} - \frac{\sum_i \sum_j Y_{ij}}{ts} \quad \text{with } \sum_j I_j = 0$$

and δ_{ij} = Deviation from regression of the i^{th} provenance at j^{th} environment

Two parameters of stability were calculated namely, (a) regression coefficient which is the regression of the performance of each clone under different growth periods on the growth period means and (b) mean square deviations from linear regression.
The regression coefficient is estimated as

$$bi = \sum_j Y_{ij} I_j / \sum_j I_j^2$$

where,

$\sum_j Y_{ij} I_j$ is the sum of products and

$\sum_j I_j^2$ is the sum of squares

Mean square deviations (Sd^{-2}) from linear regression is estimated as

$$\frac{\sum_j \delta^2_{ij}}{(s-2)} - \frac{S^2_e}{r}$$

where,

$$\sum \delta^2_{ij} = \left[\sum_j Y^2_{ij} - \frac{Y^2_i}{t} \right] - \frac{(\sum_j Y_{ij} I_j)^2}{\sum_j I^2_j}$$

and S^2_e = Estimate of pooled error

3.0 Results and Discussion

"The importance of selecting stable genotypes by testing the available selections at different growth phases, fertility regimes or locations have been highlighted by several researchers as G x E interaction can reduce genetic gains or make a tree breeding programme more complex and expensive". (14, 15, 16, 17]

3.1 Pooled ANOVA

The results of the pooled ANOVA for the three characters studied are presented in Table 2. The sources of variation namely, provenance, environment, provenance x environment, environment + (provenance x environment) and environment (linear) were significant at 5 per cent level for tree height, dbh and volume index.

Table 2. Pooled Analysis of Variance for phenotypic stability

Source	DF	Tree Height	DBH	Volume Index
Provenance	22	1.554*	12.809*	25.339*
Environment	4	2605.500*	1343.906*	1380.220*
Provenance x Environment	88	2.124*	3.597*	4.220*
Environment + (Provenance x Environment)	92	18.993*	7.779*	7.872*
Environment (Linear)	1	1659.119*	627.437*	601.871*
Provenance x Environment (Linear)	22	0.877*	0.875*	2.423*
Pooled Deviation	69	2.117	3.587	3.036
Pooled Error	460	0.165	0.120	0.225

* Significant at 5 per cent level

3.2 Mean Performance and Stability Parameters

The mean performance and stability parameters were worked out.

3.2.1 Tree height

The means for tree height ranged from 5.27m to 6.38 m. Provenance 18267 China recorded the minimum value whereas, Mixed Seedlot India showed the maximum value. The grand mean over the five locations was 5.70 m and 10 provenances registered higher values than the grand mean.

The regression coefficients (bi) varied between 0.819 and 1.223. All the 'bi' values were found to be around unity.

The deviation from regression ($s^{-2}di$) values ranged from -0.143 to 1.785. The s-2di values for 17 provenances were not significantly different from zero.

3.2.2 Diameter at breast height

The grand mean for DBH was 4.28 cm over the five locations and the means ranged from 3.74 cm (18137 Kenya) to 4.87 cm (Mixed Seedlot India). Twelve provenances recorded higher values than grand mean.

The 'bi' values ranged from 0.758 (18378 QLD) to 1.410 (18298 Thailand). All the provenances registered unit regression coefficient.

Clone 17577 PNG recorded the minimum value (-0.105) for deviation from regression ($s^{-2}di$) whereas, the maximum value (1.055) was registered by provenance 18298 Thailand. Eleven provenances recorded $s^{-2}di$ values around zero.

3.2.3 Volume index

The means of volume index varied between 11035.63 cm^3 and 24771.50 cm^3 with a grand mean of 15487.27 cm^3. Provenance 18136 Kenya recorded the minimum value whereas, provenance 18298 Thailand registered the maximum mean value for volume index. Ten provenances registered higher values than the grand mean.

The values for regression coefficient (bi) varied from 0.513 (18378 QLD) to 1.741 (18298 Thailand) and all the provenances recorded values around unity.

The s-2di values for 13 provenances were found around zero. The minimum and maximum values were registered by provenances 17577 PNG (-1.985) and Palacherla A (4.294) respectively.

"In the present study, stability parameters were estimated using the model proposed by Eberhart and Russel (1966)" [12]. "According to them, a high yielding genotype with unit regression coefficient (bi=1) and the deviation from regression not significantly different from zero ($s^{-2}di=0$) is considered as the stable one. Provenances which possessed high mean (general mean + two SE) only were considered for classification and characterization for adaptability" [18]. "The high-yielding clones were further classified into four groups following the methodology suggested by Mehra and Ramanujam, (1979)" [19].

Table 3. Classification of genotypes based on stability parameters

Group	Mean	Regression Coefficient 'bi'	Deviation from Regression '$s^{-2}di$'
I	High	Around unity	Around zero
II	High	Significantly deviating from unity	Around zero
III	High	Significantly deviating from unity	Significantly deviating from zero
IV	High	Around unity	Significantly deviating from zero

Clones in group I will be highly stable over the environments. An above or below average response could be expected from clones falling in group II and they will be suited for stressed or favourable environments. Groups III and IV may be ignored as the behaviour of the clones falling in these groups will be unpredictable. When the data for tree height, DBH and volume index recorded from five locations at 3 years of age were subjected to stability analysis, the variance due to clone x growth period interaction was found significant for all

these characters. Therefore, further analyses were carried out for these characters and stability parameters worked out.

Table 4. Grouping of clones based on stability parameters.

Characters	Group I	Group II	Group III	Group IV
Tree Height	18144 Kenya 18160 Malaysia 18298 Thailand 18355 Benin 18268 China Palacherla A India Mixed Seedlot India	Nil	Nil	18298 Thailand 18586 China
DBH	18160 Malaysia 18357 Philippines 18268 China Palacherla A India	Nil	Nil	18144 Kenya 18298 Thailand 18378 QLD 18586 China Mixed Seedlot India
Volume Index	18144 Kenya 18160 Malaysia 18355 Benin 18268 China Palacherla A	Nil	Nil	18297 Thailand 18298 Thailand 18378 QLD 18153 PNG 18586 China Mixed Seedlot India

Provenances, 18144 Kenya, 18160 Malaysia, 18298 Thailand, 18355 Benin, 18268 China, Palacherla A India and Mixed Seedlot India 5 were included in group I when stability parameters for tree height was considered and hence are the most stable clones with respect

to tree height (Table 4). 18298 Thailand and 18586 China though recorded high mean values, were found unpredictable over growth periods due to the significant deviation from regression. Four provenances namely, 18160 Malaysia, 18357 Philippines, 18268 China and Palacherla A India exhibited stability for DBH. Five provenances, 18144 Kenya, 18160 Malaysia, 18355 Benin, 18268 China and Palacherla A proved to be stable across the five locations with respect to volume index. No provenances were found suitable for planting in sites with stress or favourable conditions.

Table 5. Stability parameters for tree height

Provenances	Mean (m)	B	SE(B)	T	MSD	r	Prob
1	5.540	0.883*	0.119	-0.983	-0.047**	0.9823	0.5449
2	5.650	1.005*	0.202	0.027	0.178**	0.9611	0.1000
3	5.409	0.876*	0.322	-0.385	0.705	0.8808	0.0017
4	5.608	1.034*	0.109	0.317	-0.066**	0.9891	0.6109
5	5.356	1.011*	0.163	0.07	0.059**	0.9745	0.2528
6	5.558	1.095*	0.116	0.823	-0.052**	0.9889	0.5630
7	5.537	1.022*	0.233	0.095	0.289	0.9507	0.0409
8	5.423	0.987*	0.167	-0.077	0.07**	0.972	0.2328
9	5.860	1.177*	0.179	0.991	0.104**	0.9774	0.1802
10	6.006	0.944*	0.051	-1.091	-0.143**	0.9971	0.3766
11	5.274	0.819*	0.482	-0.376	1.785	0.7423	0.0000
12	5.572	1.153*	0.265	0.577	0.424	0.9499	0.0139
13	6.198	1.223*	0.221	1.011	0.243**	0.9685	0.0593
14	5.398	0.869*	0.094	-1.398	-0.091**	0.9885	0.6798
15	5.694	0.82*	0.189	-0.952	0.135**	0.9495	0.1410
16	5.785	1.045*	0.079	0.576	-0.113**	0.9944	0.6708
17	5.768	0.867*	0.194	-0.686	0.150**	0.9525	0.1257
18	5.061	0.985*	0.155	-0.094	0.037**	0.9759	0.3003
19	6.051	0.997*	0.328	-0.008	0.739	0.9022	0.0014
20	6.249	1.074*	0.088	0.836	-0.100**	0.9933	0.6883
21	5.794	0.965*	0.12	-0.289	-0.044**	0.9849	0.5371
22	5.918	1.069*	0.09	0.76	-0.096**	0.9929	0.6862
23	6.380	1.077*	0.165	0.462	0.065**	0.9769	0.2426

* Regression coefficient (B) around unity.

** Mean square deviation (MSD) from regression not significantly deviating from zero.

B = Regression Coefficient; SE(B)=Standard Error of B; T=(B-1)/SE(B) with
DF = (No. of environments -2) is used to test the hypothesis `B=1';
MSD = The stability parameter calculated from the mean square deviation from linear regression.

Table 6. Stability parameters for diameter at breast height

Provenances	Mean (cm)	B	SE(B)	T	MSD	r	Prob
1	3.902	0.779*	0.062	-3.533	-0.105**	0.9936	0.3601
2	4.099	0.974*	0.348	-0.075	0.354	0.8870	0.0087
3	4.034	0.864*	0.306	-0.445	0.247	0.8886	0.0276
4	4.202	0.849*	0.461	-0.328	0.714	0.7722	0.0003
5	3.994	0.916*	0.273	-0.308	0.172**	0.9185	0.0635
6	3.882	1.167*	0.147	1.132	-0.035**	0.9843	0.5503
7	3.739	0.873*	0.387	-0.329	0.468	0.8354	0.0027
8	4.236	0.988*	0.273	-0.043	0.171**	0.9293	0.0639
9	4.491	1.270*	0.37	0.731	0.417	0.9218	0.0045
10	4.576	0.981*	0.168	-0.116	-0.010**	0.9716	0.4342
11	3.935	0.778*	0.543	-0.409	1.038	0.6721	0.0000
12	4.297	1.213*	0.27	0.788	0.166**	0.9527	0.0676
13	4.928	1.410*	0.547	0.749	1.055	0.8691	0.0000
14	3.776	0.790*	0.263	-0.801	0.150**	0.9005	0.0805
15	4.623	0.758*	0.513	-0.472	0.914	0.6854	0.0001
16	4.304	0.933*	0.335	-0.2	0.32	0.8858	0.0124
17	4.401	0.909*	0.158	-0.575	-0.022**	0.9706	0.4875
18	3.865	0.926*	0.236	-0.314	0.098**	0.9392	0.1425
19	4.570	1.049*	0.316	0.155	0.273	0.9166	0.0208
20	4.296	1.114*	0.339	0.338	0.33	0.9154	0.0112
21	4.512	1.078*	0.179	0.438	0.006**	0.9731	0.3716
22	4.869	1.266*	0.145	1.839	-0.038**	0.9871	0.5645
23	4.870	1.116*	0.391	0.297	0.478	0.8909	0.0025

* Regression coefficient (B) around unity

** Mean square deviations (MSD) from regression not significantly deviating from zero.

B = Regression Coefficient; SE(B)=Standard Error of B; T=(B-1)/SE(B) with
DF = (No. of environments -2) is used to test the hypothesis `B=1';
MSD = The stability parameter calculated from the mean square deviation from linear regression.

Table 7. Stability parameters for volume index

Provenances	Mean (cm^3)	B	SE(B)	T	MSD	r	Prob
1	11550.04	0.702*	0.15	-1.985	3281302.50**	0.9563	0.6131
2	14701.23	1.112*	0.367	0.305	20955008.00	0.9016	0.0139
3	13254.56	0.908*	0.253	-0.363	5700342.00 **	0.9278	0.1645
4	13111.31	0.716*	0.187	-1.515	569532.31**	0.9359	0.4279
5	12057.10	0.716*	0.196	-1.447	169310.63 **	0.9301	0.3841
6	13786.06	1.068*	0.142	0.477	3815954.00 **	0.9827	0.6471
7	12346.76	0.838*	0.312	-0.52	12858575.00	0.8781	0.0518
8	14030.79	0.976*	0.277	-0.088	8369524.00 **	0.9255	0.1075
9	19024.14	1.531*	0.316	1.681	13383915.00	0.9591	0.0475
10	16846.74	1.073*	0.117	0.623	5212043.00 **	0.9883	0.6863
11	11867.63	0.717*	0.469	-0.604	39361884.00	0.6997	0.0009
12	16556.47	1.196*	0.343	0.572	17255248.00	0.9239	0.0252
13	24771.50	1.741*	0.581	1.274	64722572.00	0.8996	0.0001
14	10704.29	0.680*	0.248	-1.29	5097564.50 **	0.8829	0.1808
15	15352.67	0.513*	0.412	-1.182	28460454.00	0.6076	0.0043
16	14788.14	0.789*	0.323	-0.651	14414951.00	0.8562	0.0401
17	14792.73	0.877*	0.067	-1.823	7155802.00 **	0.9941	0.3403
18	11035.63	0.729*	0.205	-1.318	963285.38 **	0.9264	0.3412
19	19005.02	1.125*	0.708	0.177	99911224.00	0.7164	0.0000
20	17249.98	1.215*	0.222	0.968	2484895.00 **	0.9677	0.2710
21	16507.23	1.114*	0.248	0.461	5101040.00 **	0.9528	0.1807
22	20670.70	1.409*	0.095	4.294	6180423.00 **	0.9954	0.6036
23	22196.35	1.255*	0.595	0.429	68074416.00	0.8167	0.0000

* Regression coefficient (B) around unity

** Mean square deviations (MSD) from regression not significantly deviating from zero.

B = Regression Coefficient; SE(B)=Standard Error of B; T=(B-1)/SE(B) with
DF = (No. of environments -2) is used to test the hypothesis `B=1';
MSD = The stability parameter calculated from the mean square deviation from linear regression.

4.0 Conclusions

Provenances, 18144 Kenya, 18160 Malaysia, 18298 Thailand, 18355 Benin, 18268 China, Palacherla A India and Mixed Seedlot India 5 were included in group I when stability parameters for tree height was considered and hence are the most stable clones with respect to tree height. 18298 Thailand and 18586 China though recorded high mean values, were found unpredictable over growth periods due to the significant deviation from regression. Four provenances namely, 18160 Malaysia, 18357 Philippines, 18268 China and Palacherla A India exhibited stability for DBH. Five provenances, 18144 Kenya, 18160 Malaysia, 18355 Benin, 18268 China and Palacherla A proved to be stable across the five locations with respect to volume index. No provenances were found suitable for planting in sites with stress or favourable conditions. Stable provenances identified could be utilized for further breeding programmes.

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