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Experimental Design for Evaluation of Clones of Casuarina for Windbreak Agroforestry System

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ABSTRACT

Institute of Forest Genetics and Tree Breeding, Coimbatore took an initiative in ideotype breeding to select superior phenotypes of *Casuarina* which are efficacious for a windbreak agroforestry system. 21 phenotypes of Casuarina were selected by adopting 'point grading method'. Trees having more branches were given additional weighted score. On the basis of rooting ability and within clone variation in growth traits, ten clones were short listed for field trials. The total perimeter of the field was divided into two halves. Each half of perimeter was further divided into 20 m long sections. In each section of perimeter, one clone was planted in three rows. Each row is considered as a separate block (Replication) as trees in each row will be experiencing different growing conditions. The spacing between the rows was 1 m and the spacing within rows was 2 m in zig-zag configuration. The check clone was a hybrid clone of *Casuarina equisetifolia* x *Casuarina junghuhniana* – a commonly planted clone in Tamil Nadu. By dividing cumulative superiority percentage by 100, a "Cumulative Superiority Index" has been developed for final ranking. As a significant outcome of this experiment, five superior clones have been released for commercial planting with approval of Varity Release Committee of Indian Council of Forestry Research and Education, Dehra Dun – an apex body for approving release of tree varieties in India.

Key Words:

Branching traits, Casuarina, Cumulative Superiority Index, Windbreak agroforestry system, Windbreak clones,

INTRODUCTION

A windbreak is a narrow row of trees planted in fields bordering a farm plot. Windbreaks on field boundaries effectively control injuries to the tender crops from sand blasting and hot wind. It is reported that it reduces wind velocity by 20-46% and soil loss by 76% (Gupta et al. 1997). Windbreaks are an important tool for farming particularly in semi-arid areas. Besides crop protection and enhanced productivity, the windbreaks contribute to the organic matter content of the soil through leaf fall. Further, because windbreaks control wind speed behind the barrier, they reduce evaporation from bare soil and transpiration from crops thus making plants

behind the windbreak less likely to suffer from moisture stress and reducing the irrigation requirements. By considering the above facts, windbreak Agroforestry system can be promoted to make the agro-ecosystems as climate change resilient system through i) enhanced productivity, ii) reduced evapo-transpiration and in turn increased water use efficiency of the agro-ecosystem iii) reduced crop damage particularly in plantain cultivation in Tamil Nadu and iv) increasing carbon sequestration in biomass and in soil.

Banana is the third important commercial crop in the western zone of Tamil Nadu State, India. It is planted in about 30,000 ha of land and the annual fruit production is around1.1 million metric tones (TNAU 2000). The estimated loss due to wind damage for the banana growers is about USD 77,000 per year (Anon 2013). The Institute of Forest Genetics and Tree Breeding (IFGTB) Coimbatore initiated selection of Casuarina phenotypes suitable for windbreaks. Certain phenotypes of *C. equisetifolia* and *C. junghuhniana* have shown unique branching characteristics which are ideal for the services sought from windbreaks (Nicodemus et al., 2001). Such phenotypes can be selected for developing windbreaks in banana-growing belt of the western zone of Tamil Nadu, which faces strong gusty winds during monsoon periods. The present study was carried out to select and evaluate the suitable phenotypes of casuarina for windbreak agroforestry system. In this effort, while establishing field trials, an innovative experimental design was framed for simultaneous evaluation for i) superiority of clones for growth traits and ii) efficacy of these clones for wind speed reduction. The new method adopted and the results of the study are discussed in this paper.

MATERIALS AND METHODS

Selection of superior phenotypes

Twenty one phenotypes of casuarina were selected from plantations in different locations of Tamil Nadu, India *viz*., Mayiladuthurai, Karur, Tiruppur, Cuddalore, Erode, Neyveli, Tirupati and Coimbatore. 'Point grading method' adopted by Jayaraj et al (1998) was used for selection of candidate phenotypes for windbreaks with modification by assigning greater score for more branchiness and other branch related traits. The candidate phenotypes were selected by comparing with the rest of the trees in each plantation in terms of height and diametrical growth as well as on the basis of branch characteristics.

Establishment of clonal bank

The branch cuttings collected from selected phenotypes were rooted and evaluated for rooting potential which showed large variation. After evaluating the rooting potential, a clonal bank was established in IFGTB campus at Coimbatore, Tamil Nadu, India. Early height growth rate was closely monitored on monthly basis for two years. Ten clones were selected based on the rooting ability and initial growth in clonal bank. These clones were further propagated to raise multi-location field trials for evaluating their superiority in terms of growth and branching traits under windbreak agroforestry systems.

Establishment of multi-location field trials

Three representative farm areas were identified where the damage to banana crop occurred earlier. The selected farms were located at 1) Idikarai (latitude:11° 07' N, longitude: 77° 58' E, altitude: 418 m, soil type: calcareous black soil), 2) Kovilpalayam (latitude:11° 10' N, longitude: 77° 07' E, altitude: 499 m, soil type: red gravely soil), and 3) Narasimmanaicken Palayam (latitude:11° 07' N, longitude: 76° 58' E, altitude: 325 m, soil type: deep black clayey soil).

Planting configuration

The shortlisted 10 windbreak clones were planted in three rows along the boundaries of a banana plantation as a windbreak agroforestry system. A widely planted hybrid clone of *C. junghuhniana* x *C. equisetifolia* and a seedling accession were used as benchmark. The spacing between the rows was 1 m and the spacing within rows was 2 m. Pattern adopted was zig-zag

configuration (Quincunx planting method) as depicted in Fig. 1.

While establishing field trials, an innovative experimental design was framed for simultaneous evaluation for i) superiority of clones for growth traits and ii) efficacy of these clones for wind speed reduction. In this innovative design, the total perimeter of the field was divided into two halves. Each half of perimeter was further divided into 20 m long sections. In each section of perimeter, one clone was planted in three rows. Each row is considered as a separate block (Replication) as trees in each row will be experiencing different growing conditions.

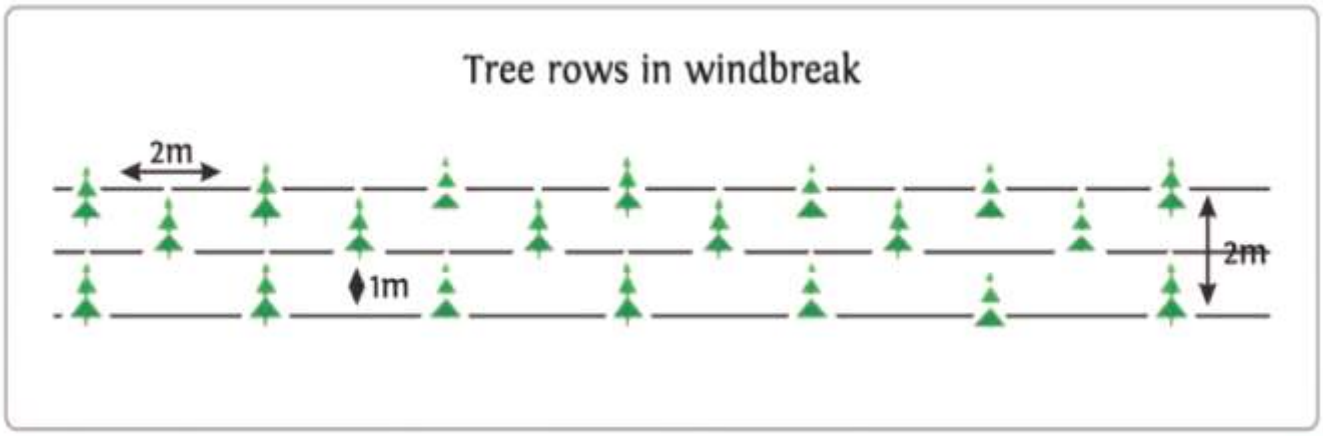

Fig. 1: Planting configuration adopted in clonal trials in windbreak agroforestry system in Tamil Nadu, India

Data collection and Analysis

Data has been collected on six traits *viz.* girth at breast height (cm), total height (m), number of branches up to 3 m height from the ground, branch length (cm), branch thickness in mm (mid-girth of branch) and branch angle in degrees (to the main stem) at the age of 1.5 years. Superiority of test clones over check clone was calculated for each of the six traits. Finally superiority percentage for the six traits was added. By dividing cumulative superiority percentage by 100, a "Cumulative Superiority Index" has been developed for final ranking.

Cumulative Superiority Index = Cumulative superiority percentage for six traits / 100

RESULTS AND DISCUSSIONS

Growth characteristics

Grand mean girth of Casuarina was 10.96 cm and the greater girth was recorded in clones CJ-17 (13.30 cm), CJ-18 (12.98 cm) and CJ-8 (12.68 cm). The least girth recorded was 7.41 cm for clone CJ-20. Similarly, greater mean height was recorded for clones CJ-7, CJ-8 and CJ-17 as 6.45 m, 6.21 m and 5.86 m respectively against the grand mean height of 5.28 m. Clone of *Casuarina equisetifolia* (CE-15) recorded girth of 10.09 cm

and height of 4.02 m. In general, clones of *Casuarina junghuhniana* recorded greater girth and height growth when compared to *C. equisetifolia* in all three field trials in the present study (Table 1). In Tamil Nadu, the reported overall mean annual increment (MAI) for girth and height in *Casuarina equisetifolia* observed were 8.3 cm year^{-1} and 4.4 m year^{-1} respectively (Ravi, 2011). Nicodemus et al (2015) also reported that studies on species and provenance variation among six species of Casuarina showed that *Casuarina junghuhniana* was the most adaptable and fastest growing species which registered 54% more volume growth than *C. equisetifolia*. Seedling origin trees not only registered lower girth but also showed huge variation among individual trees within an even-aged plantation. Ravi (2011) also reported huge variation in girth in 2-year-old seedling origin plantations of *Casuarina equisetifolia* ranging from 9.0 to 20.0 cm. Similarly, Buvaneswaran et al (2010) reported wide difference between the minimum (15.5 cm) and maximum girth (73.5 cm) within an even-aged seedling origin plantation of *Casuarina equisetifolia* with co-efficient of variation as 27.2%. Ravi et al (2013) also reviewed similar variations reported in seedling origin plantations and suggested for introduction of uniform and superior planting stock in Casuarina for enhancing productivity in this species. Hence, it can be concluded that by considering huge variation in growth of seedling origin trees as well as lesser productivity, it would be better to use superior clones for establishing windbreaks for uniform growth and higher productivity.

With reference to height growth (Table 1), top three clones viz. CJ-7, CJ-8 and CJ-17 registered 57%, 51% and 43% respectively more height growth than that of check clone (CJ-12). It is reported that the sheltered area may go up to 15 to 25 times the height of the windbreaks on the leeward side and 2 to 3 times on the windward side when the wind is 40 km per hour (Dwivedi, 1992) which emphasizes the importance of height of the trees in windbreaks. Further, the rate of height growth also should be at least equivalent to that of the banana crop, in this case, so that the windbreaks protect at the harvest stage of the current banana crop itself. The selected superior clones of *C. junghuhniana* registered such high rate of height growth and were matching with rate of height growth of banana crop.

Table 1. Growth and branch characteristics of clones of Casuarina (CJ-5, CJ-6, CJ-7, CJ-8, CJ-9, CJ-17, CJ-18, CJ-20, CE-15, Seedlings and CJ-12) under windbreak agroforestry system in Tamil Nadu, India (Age – 1.5 years)

Clone Number	Girth (cm)	Total height (m)	Number of branches	Branch length (cm)	Branch angle (degrees)	Branch thickness (mm)
CJ-5	12.16 ± 0.69	5.14 ± 0.99	39.00 ± 4.62	111.00 ± 8.11	78.57 ± 0.80	15.67 ± 2.96
CJ-6	11.63 ± 0.62	5.80 ± 0.12	45.00 ± 1.73	136.63 ± 2.34	80.40 ± 0.46	16.00 ± 0.58
CJ-7	10.82 ± 0.76	6.45 ± 0.31	37.00 ± 3.21	100.00 ± 12.78	76.63 ± 2.65	14.67 ± 0.88
CJ-8	12.68 ± 1.96	6.21 ± 0.97	38.00 ± 4.62	157.50 ± 1.17	66.67 ± 3.68	21.67 ± 1.33
CJ-9	11.76 ± 2.71	5.76 ± 0.61	35.67 ± 7.69	168.37 ± 24.25	69.93 ± 4.47	18.33 ± 2.40
CJ-17	13.30 ± 3.78	5.86 ± 0.76	36.00 ± 4.62	116.83 ± 19.41	83.87 ± 0.64	18.67 ± 2.19

Clone Number	Girth (cm)	Total height (m)	Number of branches	Branch length (cm)	Branch angle (degrees)	Branch thickness (mm)
CJ-18	12.98 ± 3.37	5.72 ± 0.41	39.33 ± 6.23	141.53 ± 13.80	69.17 ± 5.17	19.00 ± 2.31
CJ-20	7.41 ± 0.66	5.35 ± 0.78	38.33 ± 5.04	117.97 ± 10.01	68.30 ± 5.01	17.00 ± 1.53
CE-15	10.09 ± 2.38	4.02 ± 0.64	44.00 ± 0.01	125.93 ± 17.87	71.40 ± 3.12	17.67 ± 1.86
Seedlings	9.53 ± 0.04	3.70 ± 0.40	38.33 ± 3.76	115.87 ± 11.92	81.10 ± 0.81	18.00 ± 2.31
CJ-12 (Check clone)	8.21 ± 0.02	4.10 ± 0.56	38.00 ± 3.79	91.40 ± 10.24	65.03 ± 3.78	15.00 ± 2.00
Grand Mean	**10.96**	**5.28**	**38.97**	**125.73**	**73.73**	**17.42**

Branching traits of clones across four locations

The selected clones were evaluated for four major branching traits *viz.,* a) number of branches, b) branch length, c) branch angle and d) branch thickness which will have bearing on efficacy of windbreaks. More the number of branches, greater will be the density of foliage and in turn lesser will be the porosity and optimum porosity of windbreaks will be obtained for better protection from wind. Table-1 presents the data on number of branches recorded up to three meter height of the main stem from the base of the trees. Highest number of branches (45) was recorded in Clone CJ-6 which was 18% more than that of check clone (CJ-12).

Branch length was considered as a superior trait for clones being selected for windbreaks, as greater the length of branch, lesser the number of trees required per unit length of the windbreaks which will also help in increasing density of the foliage in the interspaces of trees in a windbreak row. Among the four branching traits studied, superiority of the best clones over check clone was greater for branch length (up to 84% in clone CJ-9) when compared to other three traits *viz.,* branch thickness (up to 44% in clone CJ-8), branch angle (up to 29% in clone CJ-17) and number of branches (up to 18% in clone CJ-6). Branch length was more than one meter with in a period of 2 years (Table 1). Hence, the interspaces of 2 m given within a row of windbreaks were covered by the trees on either side of the interspaces.

Branch angle was more than 65 degrees (Table 1) in all the test clones and it was 65.03 degrees in check clone (CJ-12). The widest branch angle was recorded in CJ-17 (83.87degrees) followed by CJ-6 (80.4 degrees). Wider the branch angle, greater will be the perpendicular obstruction to the wind forces penetrating through windbreaks. On the other hand, if branch angle is acute and narrow, then more porosity will be created when wind passes through windbreaks with high speed. Similar to branch length, branch angle also determines the number trees required for a unit length of windbreaks. In other words branch angle also determines the within row spacing to be adopted in windbreaks.

Table 1 also presents the branch thickness measured in the mid-length of each main branch. The measurement was made in branches existing up to 3 m height of the main stem from the base of the trees. The assumption considered here is thicker the branch, greater will be the resistance to

the passing wind force and more effective in providing protection to the crop inside the windbreaks. The highest branch thickness was recorded for the clone CJ-8 (21.67 mm).

ANOVA for growth and branch characteristics

Data on all the six growth and branch traits were subjected to ANOVA test of significance (Table 2). The results revealed that among the six traits tested for significance of difference of means values, branch length and branch angle showed significant variation in mean values of ten clones tested under windbreak agroforestry system in three locations in Coimbatore, Tamil Nadu, India.

Individual superiority percentage values for six traits were added and dividing cumulative superiority percentage by 100, "Cumulative Superiority Index (CSI)" has been developed for each clone for final ranking and presented in Table 3. Top five clones viz CJ-8, CJ-6, CJ-18, CJ-17, and CJ-9 registered CSI values from 1.81 to 2.25 indicating cumulative superiority for the all the six desirable traits is about twice that of in Check

Table 2. ANOVA values (F and P-values) for six growth and branching traits clones of Casuarina under windbreak agroforestry system in Tamil Nadu, India

Traits	F calculated	F critical	P-value	Significance
Girth	0.942	2.297	0.516	Non-significant
Height	2.069		0.075	Non-significant
Number of branches	0.423		0.920	Non-significant
Branch length	2.935		0.017	Significant
Branch angle	3.988		0.003	Significant
Branch thickness	1.083		0.415	Non-significant

clone (CJ-12). The remaining test clones and trees of seedling origin registered CSI values ranging from 0.69 to 1.23. As a significant outcome of this experiment, five superior clones of *Casuarina junghuhniana* viz. IFGTB-WBC-1, IFGTB-WBC-2, IFGTB-WBC-3, IFGTB-WBC-4 and IFGTB-WBC-5 have been released for commercial planting by Varity Release Committee of Indian Council of Forestry Research and Education, Dehra Dun.

Similar to this effort, selection of new poplar clones for shelterbelts/windbreaks in Northern Liaoning Province in China has been reported by Lin et al. (2002) and they used indices in growth, cold resistance, disease infection, and insect infection for selection of clones. The clones of willows released for use in windbreaks in New Zealand have been selected on the basis of growth rate, narrow crown form, good low branch retention and long leafing period, particularly for sheltering horticultural crops (Hathaway et al. 1983). Cunninghan (1988) also opined that genetic gain in the traits desirable for windbreaks will increase the survival of planting stock, reduce the cost of establishment and improve the performance of trees as efficient components of windbreaks.

In the innovative new experimental design used in the present study, each clone was planted for a distance of 20 m which enabled to simultaneously evaluating clones both for growth and branching traits as well as for assessing the efficacy of clone in reduction of wind speed. Wind speed reduction under five superior clones (Clones CJ-6, CJ-8, CJ-9, CJ-17 and CJ-18) was assessed in one incidence using Portable Micrometeorological Data Station. The results are

Table 3. Cumulative Superiority Index (CSI) of clones for windbreak agroforestry system in Tamil Nadu, India

Clone Number	Girth (cm)	Total height (m)	Number of branches	Branch length (cm)	Branch angle (degrees)	Branch thickness (mm)	Cumulative Superiority Index (CSI)	Top five rank
CJ-5	48.11	25.37	2.63	21.44	20.82	4.47	1.23	
CJ-6	41.66	41.46	18.42	49.49	23.64	6.67	1.81	IV
CJ-7	31.79	57.32	-2.63	9.41	17.84	-2.20	1.12	
CJ-8	54.45	51.46	0.00	72.32	2.52	44.47	2.25	I
CJ-9	43.24	40.49	-6.13	84.21	7.53	22.20	1.92	II
CJ-17	62.00	42.93	-5.26	27.82	28.97	24.47	1.81	V
CJ-18	58.10	39.51	3.50	54.85	6.37	26.67	1.89	III
CJ-20	-9.74	30.49	0.87	29.07	5.03	13.33	0.69	
CE-15	22.90	-1.95	15.79	37.78	9.80	17.80	1.02	
Seedlings	16.08	-9.76	0.87	26.77	24.71	20.00	0.79	
CJ-12 (Check clone)	0	0	0	0	0	0	0	

presented in Table 4. The reduction in wind speed under windbreaks with superior clones was greater and ranged from 58.45 to 67.60%, when compared to wind speed reduction under check clone (Clone CJ-12).

Table 4. Reduction in wind speed (%) under windbreaks with superior clones in farm field in Coimbatore district, Tamil Nadu, India

Clone Number	Range of wind speed in Windward side (miles s^{-1})	Mean wind speed in Windward side (miles s^{-1})	Range of wind speed in Leeward side (miles s^{-1})	Mean wind speed in Leeward side (miles s^{-1})	Reduction in wind speed (%)	Superiority over check clone
CJ-8	6.7 to 7.5	7.10	2.0 to 2.7	2.35	66.90	17.08
CJ-6	6.7 to 7.5	7.10	1.9 to 2.7	2.30	67.60	18.31
CJ-18	6.7 to 7.5	7.10	2.2 to 2.8	2.50	64.79	13.39
CJ-17	6.7 to 7.5	7.10	2.5 to 3.0	2.75	61.27	7.23
CJ-9	6.7 to 7.5	7.10	2.7 to 3.2	2.95	58.45	2.29
CJ-12 (Check clone)	6.7 to 7.5	7.10	2.7 to 3.5	3.10	57.14	0

CONCLUSION

Institute of Forest Genetics and Tree Breeding, Coimbatore took an initiative in ideotype breeding to select superior phenotypes of *Casuarina* which are efficacious for a windbreak agroforestry system. 21 phenotypes of Casuarina were selected by adopting 'point grading method'. Trees having more branches were given additional weighted score. On the basis of rooting ability and within clone variation in growth traits, ten clones were short listed for field trials. The check clone was a hybrid clone of *Casuarina equisetifolia* x *Casuarina junghuhniana* – a commonly planted clone in Tamil Nadu. Superiority of test clones of *Casuarina* under windbreak agroforestry system was compared over the Check clone for growth and branching traits. As a significant outcome of this experiment, five superior clones *Casuarina junghuhniana* have been released for commercial planting by Varity Release Committee of Indian Council of Forestry Research and Education. The innovative new experimental design used for evaluation of clones under windbreak agroforestry system was effective for simultaneous evaluation of clones for their growth and branching traits as well as for assessing on wind velocity. Further, the use of Cumulative Superiority Index is suggested while evaluating phenotypes for growth and branching traits as needed for evaluation of windbreak clones.

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