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Evaluation of interspecific hybrid clones of *Casuarina* for adaptability and growth in arid and semi-arid regions of North-West India

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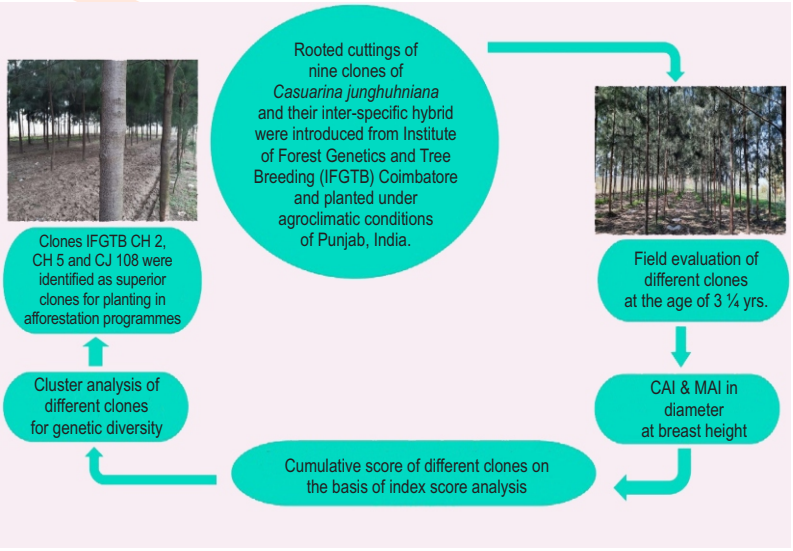
Abstract

Aim: The present study aimed at introducing high yielding clones of commercially important short rotation tree species such as *Casuarina junghuhniana* under arid and semi-arid conditions of North India and investigating their adaptability, growth and productivity potential for identification of superior clones for cultivation.

Methodology: Nine clones of *Casuarina*, four of *Casuarina junghuhniana* and five of inter-specific hybrid of *C. equisetifolia* x *C. junghuhniana*, were introduced from the Institute of Forest, Genetics and Tree Breeding, Coimbatore, Tamil Nadu and were planted at two distinct agro-climatic conditions representing the arid and semi-arid conditions of Punjab, India.

Results: The clones were studied for morphological traits (quantitative, qualitative, and fruiting) and showed significant variation in terms of adaptability, growth and branching traits under both environmental conditions. The clones IFGTB CH 2, CH 5 and CJ 108 were found superior for growth, stem quality characters and adaptability for which the data were recorded at the age of 2 ¼ and 3 ¼ yrs.



Interpretation: Findings of the current study will contribute in the adoption of selected clones in agroforestry situations. Further, field testing is required to estimate the yield potential of shortlisted clones and to broaden the genetic diversity of planting material through introduction of more number of clones.

Key words: *Casuarina junghuhniana*, Clones, Heritability, Semi arid region

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Introduction

Punjab, a north-western state of India, is primarily an agrarian and progressive state of India and about 83 percent of its geographical area is under intensive cultivation. Paddy-wheat crop rotation system is followed by most of the farmers. The tree cover in this state is meagre (6.83% of its geographical area including natural and planted forests) as against the minimum 33% requirement prescribed under the National Forest Policy, with almost no land available for sole cultivation of trees. Agroforestry has contributed significantly in enhancing the area under tree cover in the past three decades and about half of the total trees of the state are under Trees outside Forests (TOF). Agroforestry has been recognised worldwide to solve the problems related to insufficient supply of timber, fuelwood, fodder, ensuring livelihood security of underprivileged people and mitigating the challenges of climate change and global warming. Thus, governments are taking steps to increase area under agroforestry plantations. The total area under agroforestry at global level is 1023 million ha (FAO 2000). The current area under agroforestry in India is estimated to be 25.32 million ha which accounts to 8.2 per cent of the total geographical area of the country. There is an urgent need to adopt agroforestry at large scale in the country to become self-sufficient in wood supply, increasing area under forest and tree cover, improving soil health, and increasing productivity of degraded lands.

A total of 53.32 million ha area which accounts to about 17.57 per cent of the total reported geographical area of India, could potentially be under agroforestry in the near future, thus making agroforestry a major land-use activity, after agriculture and forestry (Dhyani *et al.,* 2013).The farmers of this state are very enthusiastic and eager to accept new technologies and a large number of farmers have grown fast-growing short-rotation tree species like *Populus, Eucalyptus, Melia*, etc., on their farmlands along with agricultural crops so that agroforestry has emerged an important land-use system contributing in improving the socio-economic conditions of farmers. However, the market price of these tree species experience fluctuations at certain times and farmers get discouraged for adopting of agroforestry systems since they have no other choice, except the above-mentioned tree species as growing other tree species is not profitable. Therefore, there is an urgent need to explore other short-rotation tree species which can be recommended to the farmers for cultivation on their farmlands. Another major problem which the state encounters is that its large area in south-western districts is under salt-affected soils posing a serious threat to agricultural productivity. Efforts need to be made to enhance the productivity of these lands by planting short rotation tree species which are not only tolerant to salinity but have a high market value.

Keeping in view the above facts, genetically improved high-yielding clones of *Casuarina* were introduced in Punjab in the year 2016 from the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, Tamil Nadu for exploring the productivity potential of this tree species under arid and semi-arid conditions of Punjab, India and giving an alternative/ additional tree species for cultivation by farmers under agroforestry and salt affected areas of Punjab. *Casuarina* is one such tree species which hold great potential for growing under Punjab conditions provided high-yielding clones with fast growth rate and short rotation period are available. It is well adapted to South Indian conditions which is evident from the fact that approximately 500,000 ha area exists under *Casuarina* plantations in the coastal states of Orissa, Tamil Nadu, Andhra Pradesh and Puducherry (Nicodemus, 2009). Another estimate suggests about 800,000 ha area is under *Casuarina* plantations in India (Pinyopusarerk and Williams, 2000). *Casuarina* has gained considerable attention throughout the world due to their multiple end-uses (Turnbull, 1990). Characteristics like fast growth and low branch density with straight stem makes it an ideal species for agroforestry systems (Viswanath *et al.,* 2001) as it suits the farmer who have small landholdings (Rawat *et al.,* 2011). Salt-tolerant ability (Moezal *et al.,* 1989), nitrogen-fixing capacity (Parrotta *et al.,* 1994), fast-growing habit and commercial value of this tree species makes it a potential tree species for planting in Punjab. However, no studies have been carried out for screening and selection of *Casuarina* clones for growing Punjab conditions. Therefore, the present study was carried out to evaluate the adaptability and growth potential of high-yielding clones of *Casuarina* under Punjab conditions.

Materials and Methods

Experimental sites: The studies on clonal evaluation of *Casuarina* under agro-climatic conditions of Punjab were conducted at two sites. Site-1 (Ruldu Singh Wala University Farm, Bathinda) situated at 30°00'66" N latitude and 74°78'20" E longitude, 211 m above the mean sea level representing the arid region of Punjab with mean annual temperature of 23.8°C, annual rainfall of 633.2mm with 5-6 dry months. Soil texture of the site was loamy with soil pH 8.2-8.4 up to 60 cm depth and organic carbon content 0.12%. Site-2 (University Seed Farm, Ladhowal, Ludhiana) is situated at 30°59'28"N latitude and 75°52'38" E longitude at 240 m above the mean sea level representing the semi-arid conditions of Punjab with mean annual temperature of 23.5°C, annual rainfall of 1157.1mm with 1-2 dry months. Soil texture of the site was loamy with soil pH 8.2-8.3 up to 60 cm depth and rich in organic carbon content (0.57%). About 75% of the rainfall under both conditions is received during July to September.

Germplasm material: The rooted cuttings of nine clones of Casuarina (Four clones of *Casuarina junghuhniana* and five clones of interspecific hybrids of *C. equisetifolia* x *C. junghuhniana*) developed by the Institute of Forest Genetics and Tree Breeding, Coimbatore, were tested in the present study and their passport details are given in Table 1. Rooted cuttings were grown in polybags (size) for 4 months in Punjab Agricultural University to acclimatize them for local climatic conditions. The plants were 4-months-old and about 50-60 cm tall when field planting was done.

Experimental design and layout: Experiments were laid out in September 2016 in Randomized Block Design (RBD). Trees were planted at a uniform spacing of 4×2m with three replications having four trees of each clone in each replication at both the sites. Weeding operations and irrigation were given at regular intervals as and when required.

Observations recorded: Observations on quantitative and qualitative traits were recorded as follows:

Quantitative traits: The observations on tree height and diameter at breast height were recorded during December 2018 (at the age of 27 months) and December 2019 (at the age of 39 months). Current annual increment (CAI) and mean annual increment (MAI) were calculated using the observations of the above two parameters. Crown spread was calculated by multiplying the length and width of the tree crown. The number of branches were measured by counting the branches in one-meter length on the main stem from the lower end of the crown/ from first crown forming branch. Tree stem volume (V) was calculated by the following formula: Tree stem volume (V) = 1/3 π $(D/2)^2h$, where, d is diameter at breast height and h is tree height.

Qualitative traits: Qualitative traits *viz.* branch angle to the main stem, axis persistence to see stem forking behaviour, stem straightness and branch thickness were estimated by using the criteria and following the procedure suggested by Luechanimitchit *et al.* (2017).

Flowering and fruiting behaviour: The visual observations were recorded to study the flowering and fruiting bearing pattern in different clones under both the environments. Flowering and fruiting were considered as low, medium and high as per the following criteria: **Low:** Flowering and fruiting in less than one-fourth of the total crown area; **Medium:** Flowering and fruiting in one-fourth to half of the total crown area and **High:** Flowering and fruiting in more than half of the total crown area.

Data analysis: Data were subjected to analysis as suggested by Gomez and Gomez (1984) for interpretation of results and analysis of variance was carried as given in Table 2.

Index score analysis: Index score analysis was carried out as per the method given by Anderson (1957). Score (1, 2 or 3) was assigned for a particular trait to the clones falling in different class intervals according to their performance for traits, *i.e.,* tree height, DBH and number of branches for the two sites (Table 3). Thereafter, the cumulative score of each clone was calculated by combing together the scores assigned for different traits for a particular site for analysis of rank performance of the clones.

Clustering of genotypes: The genotypes were clustered with the assistance of computer software programme DAR win (Perrier and Jacqumoud-Collet, 2006) to study the genetic diversity on the basis of morphological traits. The data were applied to unweighted pair group method with arithmetic mean (UPGMA) analysis to generate a dendrogram.

Results and Discussion

The analysis of variance revealed significant differences among the clones for traits under study at each site. Significant differences were observed among the clones within site and across the sites for growth, quality traits and fruit bearing. *Casuarina* for its suitability as an potential agroforestry tree species, more tree height and DBH is desired combined with the lesser number of branches, low branch angle and straight stem for higher growth performance, short rotation period and high compatibility with intercrops.The clone H registered maximum tree height followed by the clone F whereas for diameter at breast height (DBH), clone F ranked first followed by the clone H under both sites (Table 4). Stem volume was maximum in the clone F closely followed by the clone H under both arid and semi-arid regions. The clone F recorded least number of branches for both arid and semi-arid regions. Crown spread was least in the clone A under arid conditions whereas under the semi-arid conditions, the clone C recorded the minimum crown spread.

Higher growth of clones under semi-arid region of Punjab as compared to arid region is mainly attributed to higher organic content and more rainfall (almost double) under the semi-arid region as compared to the other site. Higher productivity of semi-arid region as compared to arid region in *Populus deltoides* (Dhillon *et al.,* 2010; Dhillon *et al.,* 2013). Significant clone x site interaction has been observed for different growth traits in *Eucalyptus tereticornis* (Kumar and Bangarwa, 2011). Pooled over both the sites, the clones IFGTB CH 2,IFGTB CH 5 and IFGTB CJ 108 out performed other clones for most of the morphological traits. The mean annual increment for tree height was maximum in the clone H followed by the clone F for both the sites whereas current annual increment for tree height was maximum in the clone F (3.75 m) for arid conditions and clone H (2.92m) for semi-arid conditions (Fig. 1).

The mean annual increment for DBH was maximum in the clone F followed by the clone H for both the sites. The current annual increment for DBH was also maximum in the clone F for both the sites (Fig. 2: current and mean annual increments for diameter at breast height). It indicated the superiority of clone F (CH 2) as this clone not only had higher average performance for tree height and DBH but the clone was still growing at greater rate compared to other clones. The clone G (CH 4) experienced complete mortality under arid conditions and had poor survival under semi-arid conditions. Index score analysis was used to categorize the clones into best, medium and poor performers on the basis of their performance for commercially important traits *viz.* tree height, diameter and number of branches. The clones attaining greater tree height and DBH but with lesser number of branches were considered better performers and were assigned higher individual index score for that particular character. The clone F attained the maximum cumulative score of 18 followed by clone H. Scores attained by these clones was almost double than those of clones D, A, B and C.This trend is consistent with the best growth

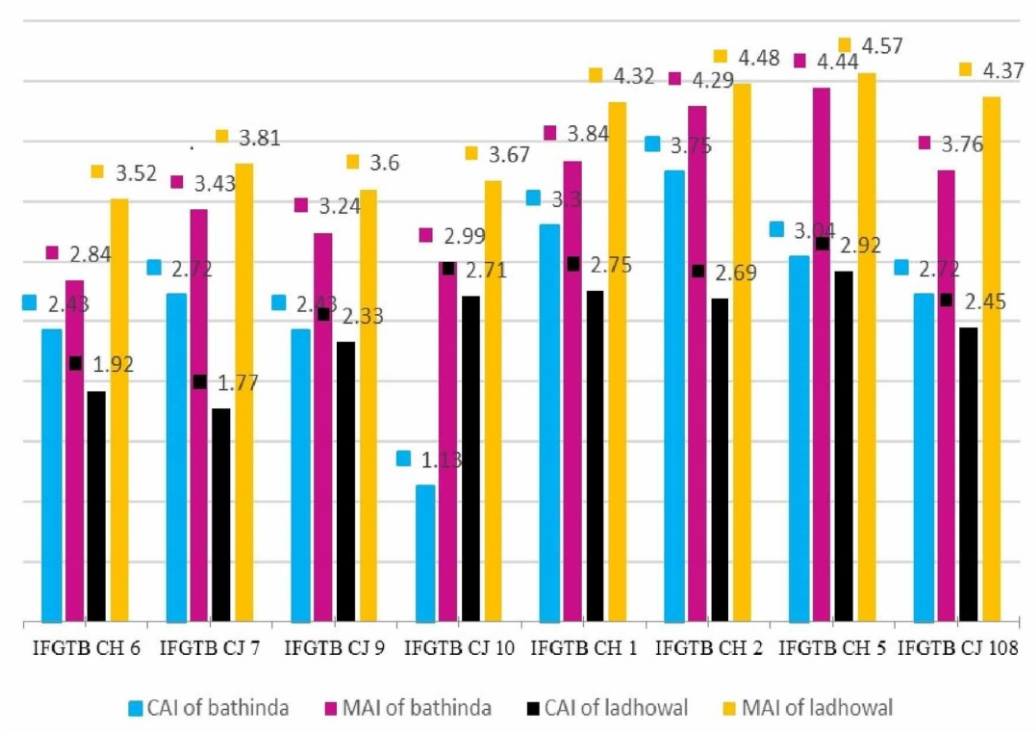

Fig. 1: Current and mean annual increment for tree height.

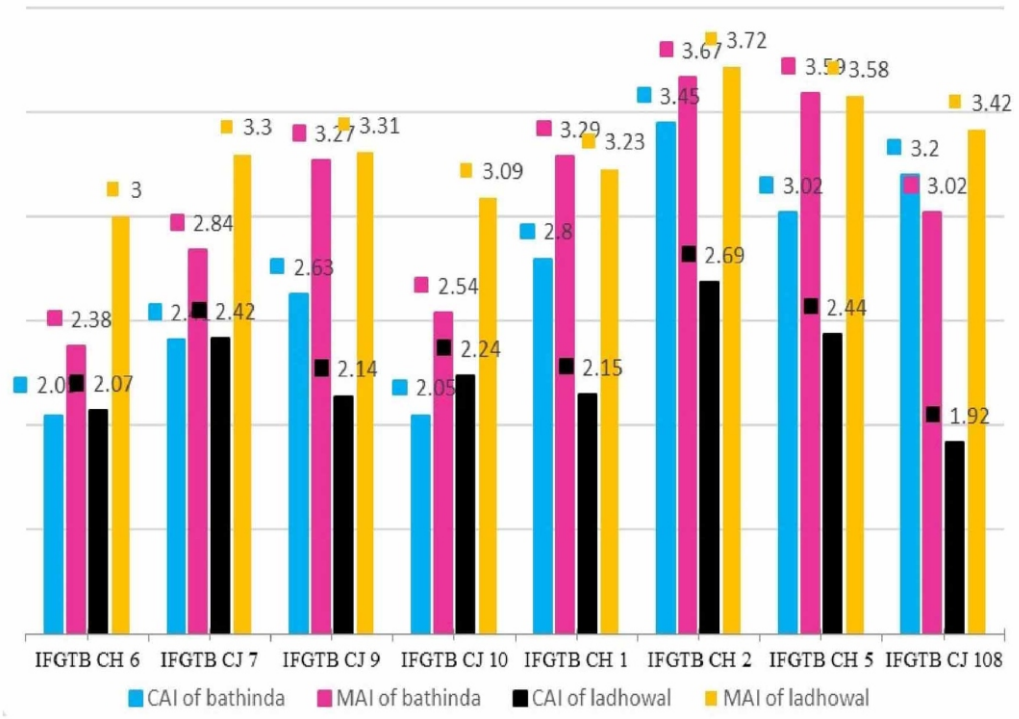

Fig. 2: Current and mean annual increments for diameter at breast height.

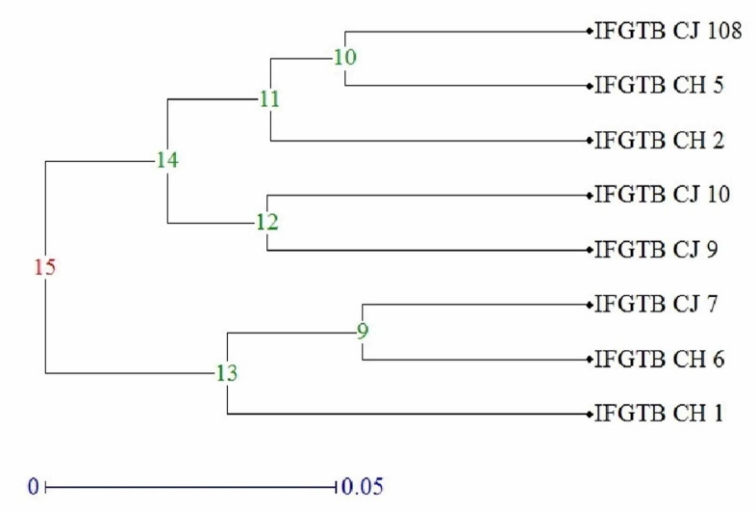

Fig. 3: Dendrogram illustrating genetic relationship among genotypes under arid conditions of Punjab, India.

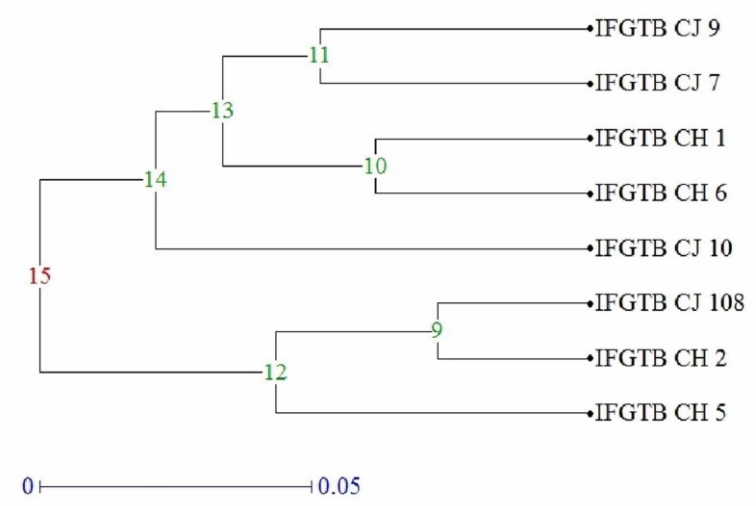

Fig. 4: Dendrogram illustrating genetic relationship among genotypes under semi-arid of Punjab, India.

observed for the clones IFGTB CH2 and IFGTBCH 5 in Andhra Pradesh (Nicodemus *et al.,* 2020). The clone IFGTB CJ 9 performed poorly, though, this clone performed well under southern regions of India (Nicodemus *et al.,* 2016) from where it has been introduced. Data clearly revealed the potentiality of *Casuarina* as suitable agroforestry tree species. Luechanimichit *et al*., (2017) observed significant differences among clones of Casuarina junghuhniana for survival, height, diameter and stem volume at 6-years of age and recommended eleven clones for commercial cultivation. In the present study, *Casuarina* attained average 13.15 m plant height and 34.04 cm girth at the age of 3 ¼ year only which shows its high productivity and suitability as short rotation tree species. Zhang *et al.* (2011) evaluated 12 clones of 6-year-old *Casuarina* trees at Hainan and Guangdong provinces and recorded tree height ranging from 13.9 to 16.3 m and diameter from 11.4 to 14.3 cm, respectively. Bassi *et al.* (2020) also reported clonal variation in *Casuarina* subjected to sodium chloride under nursery conditions. Growth differences among genotypes has been reported earlier in *Populus deltoides* (Luna *et al.,* 2011), *Eucalyptus tereticornis* (Kumar and Bangarwa 2006, 2010), *Casuarina* (Juhany *et al*., 2002; Kannan *et al*., 2012; Vishnu *et al*., 2018), *Pongamia pinnata* (Kumar 2014; Garg and Kaushik, 2021), *Salix* (Singh *et al*., 2016: Singh *et al*., 2019) and *Dalbergia sissoo* (Lamba, 1999). The morphological data were subjected to un-weighted pair group method with arithmetic mean (UPGMA) to see genetic relationship among eight genotypes.

Table 1: Description of clones

Clone No	Abbreviated form used in the text	Taxa	Pedigree
IFGTB CJ7	B	*Casuarina junghuhniana*	Selection from half-sib progeny trial (first generation)
IFGTB CJ9	C	*Casuarina junghuhniana*	Selection from half-sib progeny trial (first generation)
IFGTB CJ10	D	*Casuarina junghuhniana*	Selection from half-sib progeny trial (first generation)
IFGTB CJ108	I	*Casuarina junghuhniana*	Selection from half-sib progeny trial (second generation)
IFGTB CH1	E	Interspecific hybrid *C. equisetifolia x C. junghuhniana*	Selection from fullsib family produced by control pollination between first generation parent clones
IFGTB CH2	F	Interspecific hybrid *C. equisetifolia x C. junghuhniana*	Selection from fullsib family produced by control pollination between first generation parent clones
IFGTB CH4	G	Interspecific hybrid *C. equisetifolia x C. junghuhniana*	Selection from fullsib family produced by control pollination between first generation parent clones
IFGTB CH5	H	Interspecific hybrid *C. equisetifolia x C. junghuhniana*	Selection from fullsib family produced by control pollination between first generation parent clones
IFGTB CH6	A	Interspecific hybrid *C. junghuhniana x C. equisetifolia*	Selection from fullsib family produced by control pollination between first generation parent clones

Table 2: Analysis of variance

Source of variation	Degree of freedom	Mean of square	Fcal
Replication	(r-1)	Mr	
Treatments	(ab-1)	Mt	Mt/Me
Interaction (A × B)	(a-1) × (b-1)	MSAB	MSAB/Me
Error	(r-1) × (ab-1)	Me	
Total	(rab-1)		

Table 3: Class intervals for different traits at two sites used for index score analysis

Characters \ Scores	1	2	3
Arid conditions, Bathinda			
Tree height (m)	9.25-10.98	10.99-12.71	12.72-14.44
Diameter (cm)	7.75-9.14	9.15-10.53	10.54-11.93
Number of branches	13.33-15.00	11.67-13.32	10.00-11.66
Semi-arid conditions, Ludhiana			
Tree height (m)	11.46-12.59	12.60-13.73	13.74-14.88
Diameter (cm)	9.75-10.53	10.54-11.32	11.33-12.11
Number of branches	10.80-11.97	9.62-10.79	8.44-9.61

Cluster analysis was used to group the genotypes based on their important morphological traits. Groups were made on the basis of genetic relationship irrespective of their geographical distribution. All the genotypes were divided into two major clusters at each site. Under semi-arid conditions, cluster 1 is further divided into two sub clusters cluster 1A and cluster 1B (Fig. 3). Cluster 1A included three genotypes namely I, H and F and cluster 1B had only two genotypes namely C and D. Cluster 2 had three genotypes namely A, B and E. Phenotypic variation was observed highest in between cluster 1 and cluster 2. Under semi-arid conditions, cluster 1 comprised of five clones, *i.e.,* E, D, A, B and C whereas cluster 2 contained the clones F, H and I (Fig 4). Axis persistence was maintained by all the clones under both environmental conditions which is evident from the fact that all the clones scored more than 5 and clones forked in the top quarter of the stem. The clones F, H, A, C and D forked from near the top of

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Table 4: Performance of various clones for growth and quality traits under different environments at the age of 3 ¼ yrs

	Semi-arid region of Punjab (Ludhiana)									Arid region of Punjab (Bathinda)								
Clones	**Tree height (m)**	**DBH (cm)**	**Crown spread (m^2)**	**No. of branches**	**Stem vol. (m^3)**	**Branch angle**	**Axis pers .**	**Stem straight.**	**Branch thick.** (cm)	**Tree height**	**DBH**	**Crown spread**	**No. of branches**	**Stem vol.**	**Branch angle**	**Axis pers.**	**Stem str.**	**Branch thick.**
IFGTB CH 6	11.46	9.75	18.60	8.44	0.029	1.75	5.00	3.00	1.08	9.25	7.75	15.13	12.33	0.016	1.50	5.00	2.83	1.33
IFGTB CJ 7	12.41	10.74	21.00	11.97	0.038	1.39	5.47	2.75	1.92	11.15	9.23	16.51	12.83	0.024	1.33	5.50	3.00	1.83
IFGTB CJ 9	11.70	10.77	24.55	10.86	0.036	1.53	5.64	2.83	2.19	10.55	10.63	24.00	13.67	0.031	1.50	5.25	2.50	2.50
IFGTB CJ 10	11.93	10.07	18.55	10.83	0.032	1.83	5.67	3.00	3.17	9.73	8.42	23.11	12.44	0.019	1.17	5.89	3.00	3.00
IFGTB CH 1	14.06	10.51	20.06	10.06	0.040	1.89	5.67	2.89	1.61	12.50	10.70	20.68	15.00	0.037	1.00	5.00	3.00	2.00
IFGTB CH 2	14.56	12.11	31.60	9.11	0.059	1.44	5.00	3.31	2.94	13.95	11.93	25.09	10.00	0.054	1.50	5.75	3.25	2.75
IFGTB CH 5	14.87	11.64	26.87	9.44	0.053	2.00	5.78	3.50	3.43	14.44	11.67	23.70	12.33	0.052	1.50	5.58	3.33	3.50
IFGTBCJ 108	14.21	11.14	31.77	9.33	0.049	1.75	5.75	3.11	2.89	12.24	9.83	22.65	12.42	0.031	1.42	5.75	3.08	2.83
General mean	13.15	10.84	24.12	10.00	0.042	1.69	5.49	3.04	2.40	11.73	10.02	21.35	12.63	0.033	1.36	5.46	2.99	2.46
CD (at 5%)	1.64	1.76	10.20	2.42	0.017	0.49	NS	0.43	0.43	1.75	2.19	6.88	3.22	0.014	0.59	0.54	0.53	0.63

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tree while the remaining clones forked in the top quarter of the stem. The clones had higher superiority for stem straightness also as most of the clones recorded score of more than three which indicated that most of the clones were complete straight or near to straight. Light branching habit is a desirable character of tree species for suitability under agroforestry so that trees cause minimum shade on underlying crops. Since *Casuarina* is an evergreen tree species thus clones with light and thin branches and angle close to the main stem will be of much preference. Branch angle formed by the clones B and F under semi-arid conditions and clone E and D under arid region were near to main stem (values near to one) which is positive attribute for suitability of these clones for planting under agroforestry. The clones D and H attained score of 3 or more than 3 for branch thickness at both sites which indicate the dominance of these two clones for their light branching habit.

Among the best performing clones under study,the clone IFGTB CH 2 possessed desirable characteristics viz. high growth performance, more increment, stem straightness, low branching habit and acceptable branch angle. The present results are in accordance with the result obtained by Nicodemus *et al.* (2016) in which 10 clones of *C. junghuhniana*, two clones of *C. equisetifolia*, one seed lot of each species and a widely planted natural hybrid clone showed variation for growth and stem straightness. Marked differences were observed among the clones for fruiting and flowering behaviour. High flowering and fruiting were observed in the clones H and I and medium in the clone F.It is interesting to note that these clones have been found superior for most of the morphological traits and stem volume. Further improvement in these clones can make significant increase in yield for incorporation under afforestation programmes in agroforestry and salt affected soils of North India as low flowering occurred in Clone E. and Clones I, A, B and C did not bear flowering under both the environments.

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Add-on Information

Authors' contribution: R.K. Garg: Planning and execution of the experiment, procurement of genetic material and writing of the manuscript; **M.S. Sra:** Execution of the experiment, statistical analysis and writing of manuscript; **A. Nicodemus:** Supply of genetic material and writing of manuscript; **A. Singh:** Execution and maintenance of experiment at one site and writing of manuscript; **G. Singh:** Cluster and statistical analysis and writing manuscript.

Research content: The research content of manuscript is original and has not been published elsewhere.

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Data from other sources: Not applicable.

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