World Applied Sciences Journal 10 (2): 225-233, 2010
ISSN 1818-4952

Evaluation of *Pongamia pinnata* (L.) Pierre. Progenies for Their Growth Performance in Madhya Pradesh, India

A.K. Pandey, Nivedika Gupta, Pankaj Bhargava and Dhan Shri Sharma

Non Wood Forest Produce Division, Tropical Forest Research Institute (Indian Council of Forestry Research and Education), P.O. RFRC, Jabalpur 482021, Madhya Pradesh, India

Abstract: Biofuels derived from renewable bio-mass resources can increasingly satisfy the energy needs in an environmentally benevolent and cost effective manner while reducing dependence on import of fossil fuels and thereby providing a higher degree of national energy security. Amongst many species, which can yield oil as a source of energy in the form of biodiesel, *Pongamia pinnata* has been found to be one of the most suitable species in India. The progenies were evaluated for their growth performance in tropical conditions of Madhya Pradesh, India. The progenies were selected on the basis of oil percentage and performance of seedlings at nursery stage. The trial was established in Balaghat District of Madhya Pradesh during 2006 in randomized block design with three replications. The selected 20 progenies were evaluated for their growth performance (plant height, GBH, no. of branches and flowering pattern etc.). Growth data was recorded regularly and statistically analyzed. Among different progenies T16, T17, T10, T9, T7, T18 and T13 are performing better. Flowering and fruiting was observed in T16 Kusmeli, Chhindwara in March 2010. Performance evaluation of selected progenies will provide necessary and valuable information for establishing large scale plantations comprising of quality planting material.

Key words: *Pongamia pinnata* · Candidate plus trees (CPTs) · Progeny trial · Madhya Pradesh · Biofuel

INTRODUCTION

Diesel fuel has an essential function in the industrial economy of a developing country and used for transport of industrial, agricultural goods, operation of tractors and pump sets in agricultural sector. The requirement of petrodiesel in India is expected to grow from 55 MMT to 66.90 MMT (approx.) in 2011-12. The domestic supply of crude oil will satisfy only about 22% of the demand and the rest will have to be met from imported crude [1]. India is a big importer of crude oil and spends about Rs. 341887 crores of foreign exchange every year to meet 75% of its oil needs [2]. Fluctuating global prices, depletion of reserves, dependence on imports and environmental pollution are major concerns associated with fossils fuel energy. Therefore, need to search for alternative sources of energy which are renewable, safe and non-polluting assumes top priority in view that fossil fuel sources are finite and are the major sources of releasing sequesteral carbon to atmosphere as CO_2 and CO causing global warming.

Biofuels derived from renewable bio-mass resources can increasingly satisfy the energy needs in an environmentally benevolent and cost effective manner while reducing dependence on import of fossil fuels and thereby providing a higher degree of national energy security. Biodiesel and bioethanol have emerged as the most suitable renewable alternatives to fossil fuel as their quality constituents match diesel and petrol respectively. Biodiesel is a methyl or ethyl ester of fatty acids produced from vegetable oils, both edible and non-edible, or animal fat. Non edible vegetable oils are the most significant to use as a fuel compared to edible vegetable oils as latter has a tremendous demand for using as a food and also the high expense for production. Amongst many species, which can yield oil as a source of energy in the form of biodiesel, *Pongamia pinnata* has been found to be one of the most suitable species in India.

Pongamia pinnata (L.) Pierre. (Karanja) is a drought resistant, semi deciduous and leguminous tree of family Papilionaceae. It is a medium sized tree of 12-15 meter

Corresponding Author: A.K. Pandey, Non Wood Forest Produce Division, Tropical Forest Research Institute (Indian Council of Forestry Research and Education), P.O. RFRC, Jabalpur 482021, Madhya Pradesh, India
Phone +91-761-2840751, Fax-+91-761-2840484, Email: akpandey10@rediffmail.com

height, branches spread into hemispherical crown of dense leaves and a short bole [3]. It is indigenous to the Indian subcontinent and south-east Asia (Malaysia and Indonesia) and has been successfully introduced to humid tropical regions of the world as well as parts of Australia, New Zealand, China and the USA [4]. It is grown for ornamental purposes, as shade tree and as a wind break in tea plantations [5]. It is also cultivated along roadsides, canal banks and open farm lands. It is a preferred species for controlling soil erosion and binding sand dunes because of its dense network of lateral roots. It is one of the few nitrogen-fixing trees producing seeds containing 30-40% oil. The seeds are largely exploited for extraction of non-edible oil commercially known as 'Karanja oil'. The crude oil is yellow orange to brown in color, which deepens on standing and bitter in taste with disagreeable odour. Flowering and fruiting is observed from 5th year of plantation. It flowers in April-May and fruits mature in January-February. Commercial productions of seeds start from 10 years onwards of plantation and a fully grown tree yields up to100 kg. or even more fresh seeds per annum up to 60-70 years.

Candidate plus tree (CPTs) selection is the first and most important stage in any tree improvement programme. Identification of high yielding trees with good growth characteristics is also necessary for establishing widespread commercial-scale biodiesel feedstock plantations to meet the future energy demands. Seeds from proven source or plus trees are important factor for any successful tree improvement, afforestation and plantation programmes. Bhat and Chauhan [6] reported that source variation tests are necessary to screen the naturally existing variation to select the quality planting material for higher productivity. Therefore, the challenging task is to screen the naturally available *P.pinnata* germplasm resources to select the best/quality planting material for higher productivity. Taking the above facts into consideration, a study was carried out by Tropical Forest Research Institute, Jabalpur under national network programme on Karanja sponsored by National Oilseeds and Vegetable Oils Development (NOVOD) Board. The study highlights the attempts to select the candidate plus trees (CPTs) for higher productivity and to evaluate the performance of selected CPTs in tropical climate. The performance of selected CPTs was evaluated by conducting a progeny trial in Balaghat district of Madhya Pradesh.

MATERIALS AND METHODS

Selection of CPTs: To identify the high yielding CPTs of *Pongamia pinnata,* germplasm exploration survey was conducted during April-June 2005 at different locations in Madhya Pradesh. Total 43 CPTs were selected on the basis of phenotypic characters *viz.* age of the tree, height, crown spread, GBH (girth at breast height), yield potential, incidence of pest and diseases etc. However, the main emphasis was given to seed yield while selecting the CPTs.

The collected seeds were evaluated for their seed and pod traits and subjected to solvent extraction using Soxhlet extraction apparatus for estimation of oil content. The seed yield, seed traits and oil percentage was taken into consideration while choosing progenies for trial. The collected CPTs were analyzed and data was presented in Table 2. Statistical analysis and correlation studies of CPTs were presented in Table 3 and Table 4. The results of morphometric analysis of pod characteristics, seed characteristics and oil analysis is discussed below-

Length of Pods: The average length of pods was recorded maximum in T1 Barginagar JBP-1 (56.36 mm) followed by T3 Barginagar JBP-4 (53.79 mm) and minimum in T2 Barginagar JBP-2 (46.09 mm). The length of pods ranged from 46.09-56.36 mm, with a mean value of 50.85±2.62.

Width of Pods: The average width of pods was recorded maximum in T16 Kusmeli, Chhindwara (23.65mm) followed by T19 Chandangaon Chhindwara-2 (23.25mm) and minimum in T1 Barginagar JBP-1 (17.41mm). It ranged from 17.41-23.65mm, with a mean value of 21.35±1.58.

Weight of 100 Pods: The weight of 100 pods was recorded maximum in T20 Piparia Chhindwara (325 gm) followed by T1 Barginagar JBP-1 (310.21 gm) and minimum in T5 Bondel Jagatpur-2 (235.33 gm). It ranged from 235.33-325.00 gm, with a mean value of 296.63 ±21.89.

Total Number of Seeds: The total number of seeds in 100 pods was found maximum in T4 TFRI-07 OFK JBP (125.33) followed by T8 Maihar Satna-3 (114.33) and minimum in T6 Jhinjhri Katni-1-(83.33). It ranged from 83.33-125.33, with a mean value of 108.07±7.47.

Table 1: *Pongamia pinnata* progenies selected from various locations of Madhya Pradesh, India

S.no	Progeny	Progeny source
1	T1	Barginagar JBP-1
2	T2	Barginagar JBP-2
3	T3	Barginagar JBP-4
4	T4	TFRI-7 OFK JBP
5	T5	Bondel Jagatpur-2
6	T6	Jhinjhri Katni-1
7	T7	Maihar, Satna-2
8	T8	Maihar, Satna-3
9	T9	Nagand Road Satna
10	T10	Lalpur Satna-2
11	T11	Modhani-Satna
12	T12	Bumitha Chattarpur-1
13	T13	Khajuraho Road Panna
14	T14	Panna, Satna, Baripur
15	T15	Piparia, Pohi Seoni
16	T16	Kusmeli, Chhindwara
17	T17	Sikharpur, Chhindwara
18	T18	Chandangoan,Chhindwara-1
19	T19	Chandangoan,Chhindwara-2
20	T20	Piparia, Chhindwara

Table 2: Pod characteristics, seed characteristics and oil analysis of *Pongamia pinnata* CPTs

Progeny	Length of pods (mm)	Width of pods (mm)	Weight of 100 pod (gm)	Total no. of seeds in 100 pods	Length of seeds(mm)	Width of seeds(mm)	Weight of seeds obtained from 100 pods(gm)	No of two seeded pod	No of degraded pods	Oil percent
T1	56.36	17.41	310.21	113.00	22.43	13.48	147.59	11.00	7.00	38.82
T2	46.09	20.03	289.81	105.00	19.29	13.53	158.23	13.67	10.00	37.90
T 3	53.79	18.21	278.63	109.00	21.53	14.00	122.33	1.00	3.00	38.22
T4	48.13	19.43	250.33	125.33	20.28	13.62	125.00	14.00	7.00	36.20
T5	46.25	21.90	235.33	108.67	20.27	14.75	108.67	8.00	4.67	36.62
T6	50.19	22.36	270.00	83.33	19.35	14.57	95.33	2.33	19.00	34.64
T7	48.09	21.52	307.45	106.00	20.23	16.58	142.33	4.00	6.00	40.28
T8	49.84	21.22	301.00	114.33	21.27	17.33	145.00	3.00	5.00	40.91
T9	49.92	20.61	308.00	110.00	20.01	16.46	142.00	5.00	4.00	36.12
T10	50.78	21.60	307.65	108.81	22.05	16.45	145.00	3.00	4.00	39.20
T11	48.58	21.59	305.50	110.00	22.52	17.15	155.00	2.00	5.00	35.85
T12	52.52	22.80	301.80	107.00	21.85	17.18	161.00	3.00	7.00	34.86
T13	53.65	21.89	304.45	106.00	21.44	16.98	158.00	4.00	6.00	35.26
T14	52.98	21.52	305.45	107.00	21.58	16.96	160.00	3.00	5.33	36.37
T15	52.25	22.52	308.02	114.00	21.98	17.20	155.00	5.00	2.00	38.80
T16	51.56	23.65	306.52	105.00	22.52	17.50	158.00	6.00	8.00	36.88
T17	52.34	21.55	302.52	107.00	21.62	16.58	158.00	5.00	7.00	34.58
T18	51.54	22.65	308.00	109.00	21.58	17.35	145.00	4.00	4.00	38.78
T19	52.52	23.25	307.00	108.00	21.88	17.28	152.00	3.00	7.00	35.14
T20	49.52	21.25	325.00	105.00	22.58	16.98	155.00	2.00	4.00	39.71
Mean	50.85	21.35	296.63	108.07	21.31	16.10	144.42	5.10	6.25	37.26
SD	2.62	1.58	21.89	7.47	2.08	1.47	18.11	3.74	3.54	1.98
CD	1.49	0.88	13.75	4.492	0.934	0.869	7.08	2.108	2.233	1.34

Table 3: Analysis of variance of pod characteristics, seed characteristics and oil content in *Pongamia pinnata* CPTs

	Sum of Squares	Degree of freedom	Mean Square	F value	Significance
Length of pods	390.263	19	20.540	24.960	.000
Width of pods	141.914	19	7.469	25.753	.000
Weight of 100 pods	27299.761	19	1436.830	20.660	.000
Weight of seeds obtained from 100 pods	18686.397	19	983.495	53.384	.000
Length of seeds	61.956	19	3.261	10.145	.000
Width of seeds	123.177	19	6.483	23.356	.000
Total no. of seeds in 100 pods	3176.960	19	167.208	22.548	.000
No. of two seeded pods	798.067	19	42.004	25.716	.000
No. of degraded pods	713.917	19	37.575	20.495	.000
Oil percent	224.233	19	11.802	17.867	.000

Table 4: Correlations of pod characteristics, seed characteristics and oil content in *Pongamia pinnata* CPTs

	Length of pods	Width of pods	Weight of 100 pod	Weight of seeds obtained from 100 pods	Length of seeds	Width of seeds	Total no. of seeds in 100 pods	No of two seeded pod	No of degrade pods	Oil percent
Length of Pods	1.000	0.347	0.374	0.208	0.520	0.038	0.049	0.221	0.099	0.086
Width of pods	0.347	1.000	0.270	0.259	0.274	0.404	0.371	0.133	0.391	0.238
Weight of 100 pod	0.374	0.270	1.000	0.650	0.381	0.338	0.007	0.182	0.166	0.396
Weight of seeds obtained from 100 pods	0.208	0.259	0.650	1.000	0.337	0.241	0.373	0.266	0.312	0.188
Length of seeds	0.520	0.274	0.381	0.337	1.000	0.164	0.350	0.119	0.370	0.232
Width of seeds	0.038	0.404	0.338	0.241	0.164	1.000	0.063	0.420	0.258	0.248
Total no. of seeds in 100 pods	0.049	0.371	0.007	0.373	0.350	0.063	1.000	0.389	0.698	0.241
No of two seeded pod	0.221	0.133	0.182	0.266	0.119	0.420	0.389	1.000	0.044	0.045
No of degrade pods	0.099	0.391	0.166	0.312	0.370	0.258	0.698	0.044	1.000	0.448
Oil percent	0.086	0.238	.0396	0.188	0.232	0.248	0.241	0.045	0.448	1.000

Length of Seeds: The average length of seeds was recorded maximum in T20 Piparia Chhindwara (22.58 mm) followed by T11 Modhani Satna and T15 Piparia Pohi, Seoni (22.52 mm) and minimum in T2 Barginagar JBP-2 (19.29 mm). It ranged from 19.29-22.58 mm, with a mean value of 21.31±2.08.

Width of Seeds: The average width of seeds was recorded maximum in T15 Piparia Pohi Seoni (17.50 mm) followed by T18 Chandangaon, Chhindwara-1 (17.35 mm) and minimum in T1 Barginagar JBP-1 (13.48 mm). It ranged from 13.48-17.50 mm, with a mean value of 16.10±1.47.

Weight of Seeds Obtained from 100 Pods: The weight seeds obtained from of 100 pods was recorded maximum in T12 Bumitha Chattarpur-1 (161.00 gm) followed by T14 Panna Satna Baripur (160.00 gm) and minimum in T6 Jhinjhri Katni-1 (95.33 gm). It ranged from 95.33-161.00 gm, with a mean value of 144.42 ±18.11.

Graphical representation of variation in pod and seed characteristics of *Pongamia pinnata* is presented in Figure 1. Figure 2 represents the variation in weight of 100 pod and weight of seed obtained from 100 pods of *P. pinnata.*

Number of Two Seeded Pods: The number of two seeded pods was maximum in T4 TFRI-07 OFK JBP (14) followed by T2 Barginagar JBP-2 (13.67) and minimum in T3 Barginagar JBP-4 (1). It ranged from 1-14, with a mean value of 5.10±3.74.

Number of Degraded/aborted Pods: The number of degraded/aborted pods was maximum in T6 Jhinjhri Katni-1 (19) followed by T2 Barginagar JBP-2 (10) and minimum inT15 Piparia Pohi, Seoni (2). It ranged from 2-19, with a mean value of 6.25±3.54.

Oil Content: The oil content was found to be maximum in T8 Maihar Satna-3 (40.91%) followed by T7 Maihar Satna-2 (40.28%) and minimum in T17 Sikharpur Chhindwara (34.58%). It ranged from 34.58-40.91%, with a mean value of 37.26±1.98. Variation in oil content in different CPTs of *P.pinnata* is depicted in Figure 3.

Documentation of variation within a species is necessary for effective tree improvement and plantation programmes. Since success in establishment and productivity of forest tree plantations is determined largely by the use of proper improved planting material either in terms of seed or through clonal methods [7]. The significant variation in pod and seed characteristics and oil content can be attributed to the differences in the population, which could have been as a result of differences in the environmental conditions to which the mother plants were subjected during the growing season [8]. The data revealed significant variation in pod and seed characteristics. Similar observations with reference to relationship and variation in pod and seed characteristics were also reported by Divakara *et al.* [9] Sunil *et al.*[10], Mukta *et al.* [11] and Kaushik *et al.* [12]. In case of seed oil, significant variation was observed from the seeds collected from different sources and the value ranged from 34.58-40.91%. Systematic characterization and seed oil analysis of *P. pinnata* has been reported by Kesari *et al.* [13].

Nursery Practices: Seeds of 20 progenies were sown in nursery in the month of July 2005 in polyethene bags filled with soil, sand and farm yard manure (FYM) in the ratio of 1:1:1. Germination was observed within 10-15 days. Seeds sown in polythene bags of 15x25 cm size were found suitable to raise seedlings in nursery. The seedlings were given regular irrigation at nursery stage.

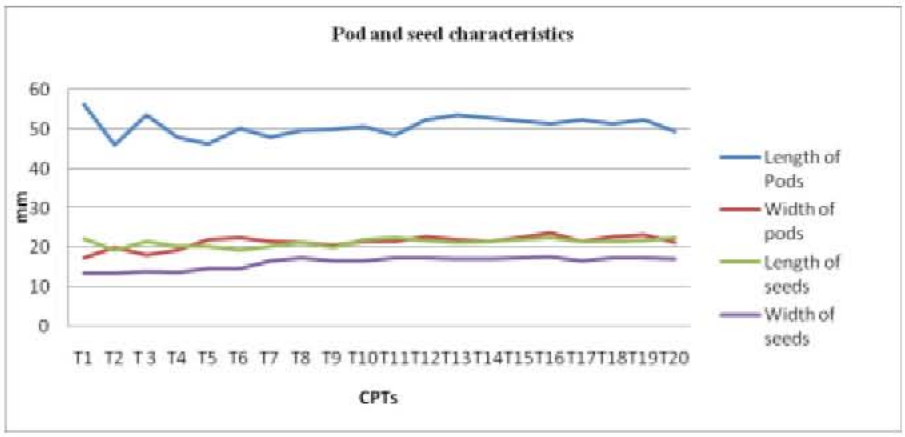

Fig. 1: Variation in pod and seed characteristics of different CPTs

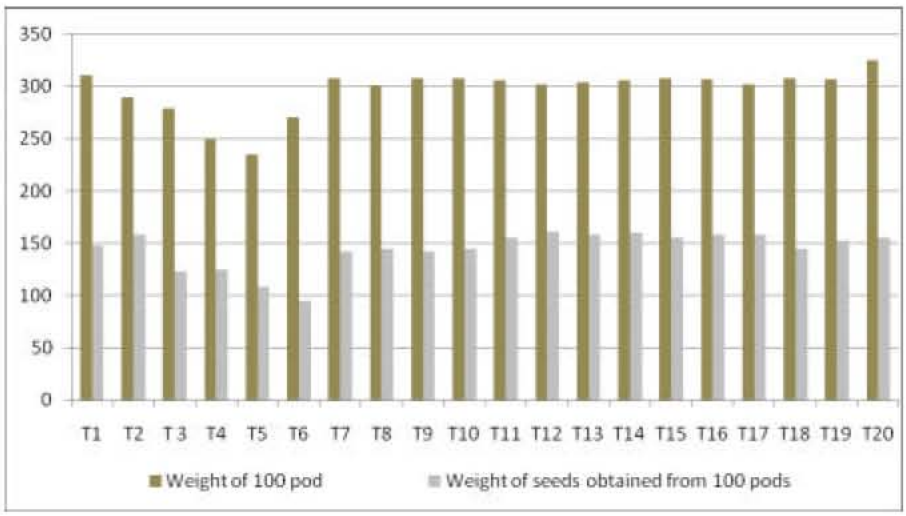

Fig. 2: Variation in weight of 100 pod and weight of seed obtained from 100 pods

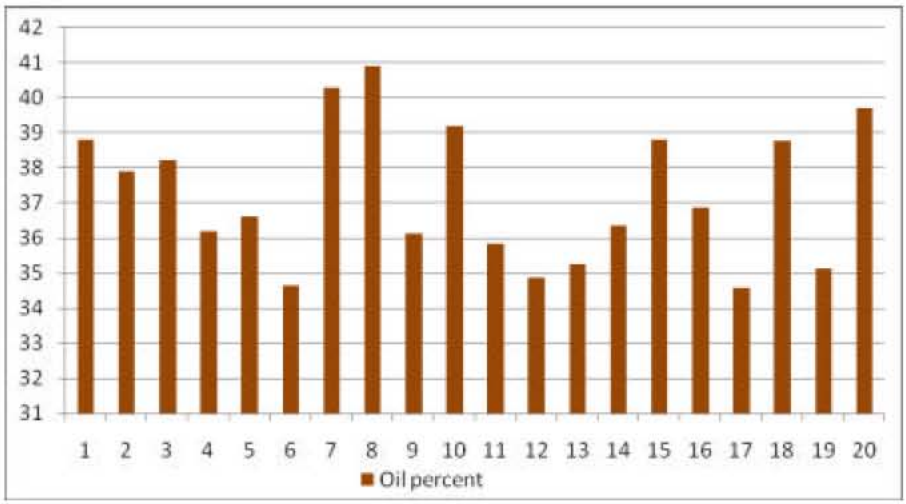

Fig. 3: Variation in oil content in different CPTs of *Pongamia pinnata*

Experimental Layout and Design: The experimental field was divided into 60 equal size blocks and 9 plants were planted in each block at the spacing of 5x5 meter. However, the experimental site has very poor soil texture (stony) with low nutrient status and low water holding capacity. The pits were dug and filled with the soil and FYM (2:1) before plantation.

Establishment of Progeny Trial: The experimental material consisted of seeds of 20 progenies selected from different locations of Madhya Pradesh. The progenies were selected on the basis of oil content and performance of seedlings at nursery stage. One year old seedlings were planted in the month of August 2006 in Randomized Block Design (RBD) in three replications.

Observation and Data Recording: Quarterly observation was taken for growth parameters like plant height, GBH (girth at breast height), number of branches, flowering pattern etc and data was recorded. A comparative study was done to find out best performing progeny on the basis of observed growth data.

Statistical Analysis: Statistical analysis and interactions between different variables were analyzed by using SX Statistix, PC DOS version 2.0 NH Analytical software and SPSS (Statistical Package for the Social Sciences, Version 14.0). Estimates of mean, standard deviation and critical difference were worked. Variance analysis was estimated for each character separately, Karl Pearson's correlation was also worked out [14]. Statistically best progeny (treatment) was determined by Duncan's multiple range test (DMRT) by using SPSS. Level of significance was defined at 0.01.

RESULTS AND DISCUSSION

Morphological growth characteristics of different Karanja progenies after three years of growth are presented in Table 5. The selected progenies showed significant difference for the studied growth parameter indicating the presence of considerable variability. The results of studied parameters are discussed below:

Plant Height: The maximum plant height was recorded in T16 Kusmeli,Chhindwara (328.78 cm) followed by T17 Sikharpur, Chhindwara (317.89 cm) and minimum in T1 Barginagar JBP-1(149.56 cm). The plant height ranged from 149.56-328.78 cm with a mean value of 232.11±54.70.

Table 5: Growth characteristics of different progenies of *P. pinnata*

Progeny	Height (cm)	GBH (cm)	No. of Branches
T1	149.56	1.56	6.56
T2	185.67	1.47	6.78
T3	185.44	1.56	7.22
T4	191.67	1.54	7.44
T5	246.67	1.67	7.67
T6	259.00	1.63	8.22
T7	278.44	2.03	12.33
T8	209.44	1.76	7.22
T9	295.00	2.49	12.22
T10	296.00	3.59	10.11
T11	222.44	2.13	8.00
T12	263.88	1.90	9.55
T13	276.56	1.94	7.11
T14	247.67	2.11	8.78
T15	242.89	2.26	10.22
T16	328.78	2.90	11.00
T17	317.89	2.82	8.67
T18	153.78	2.47	10.00
T19	152.33	2.17	9.00
T20	253.44	2.20	9.11
SD	54.70	0.55	1.78
Mean	232.11	2.09	8.71
CD	43.88	0.80	2.29

Table 6: Analysis of variance for different growth parameters in *Pongamia pinnata*

	Sum of Squares	Degree of freedom	Mean Square	F value	Sig.
Height	170578.12	19	8977.79	12.68	.000
GBH	16.79	19	0.88	3.66	.000
No of branches	167.76	19	8.83	4.55	.000

Data significant at 0.01% level

Table 7: Correlations of different growth parameters in *Pongamia pinnata*

Parameters	Treatments	Height	GBH	No of branches
Treatments	1.000			
Height	0.2477	1.000		
GBH	0.4715	0.4933	1.000	
No. of branches	0.4612	0.4536	0.4876	1.000

Table 8: Best performing progenies

		Progeny	
S. No.	Growth parameter	Progeny	Progeny source
1.	Height	T16	Kusmeli, Chhindwara
		T17	Sikharpur, Chhindwara
		T10	Lalpur, Satna-2
		T7	Maihar, Satna-2
		T13	Khajuraho road, Panna
2.	GBH	T10	Lalpur, Satna
		T16	Kusmeli, Chhindwara
		T17	Sikharpur, Chhindwara
		T9	Nagand road, Satna
		T18	Chandangaon Chhindwara
3.	Number of branches	T7	Maihar, Satna-2
		T9	Nagand road, Satna
		T16	Kusmeli, Chhindwara
		T15	Piparia Pohi, Seoni
		T10	Lalpur, Satna-2
		T18	Chandangaon Chhindwara

GBH: The maximum GBH was recorded in T10 Lalpur, Satna-2 (3.59 cm) followed by T16 Kusmeli, Chhindwara (2.90 cm) and minimum in T2 Barginagar JBP-2 (1.47 cm). The GBH ranged from 1.47-3.59 cm with a mean value of 2.09±0.55.

Number of Branches: The maximum number of branches was recorded in T7 Maihar, Satna-2 (12.33) followed by T9 Nagand road, Satna (12.22) and minimum in T1 Barginagar JBP-1 (6.56). The average number of branches ranged from 6.56-12.33 with a mean value of 8.71±1.78.

Descriptive statistical analysis and correlations with respect to morphological growth characteristics are presented in Table 6 and Table 7. The data revealed that some progenies are performing well among other under tropical conditions of Madhya Pradesh. Best performing progenies with respect to growth attributes are presented in Table 8. The analysis also revealed that growth parameters i.e. plant height, GBH and numbers of branches of selected progenies are significant and positively associated with each other. Evaluation and inter and intra-population variability of *P.pinnata* has been reported by Mukta and Sreevalli [15] and Sahu *et al.*[16] respectively. Similarly Pandey *et al.* [17] and Sakia *et al.* [14] also reported variations in growth performance of different accession/genotypes of *Jatropha curcas.* Statistically, progeny T16 Kusmeli Chhindwara was found to be superior. Flowering and fruiting was also observed in T16 Kusmeli, Chhindwara in March 2010.

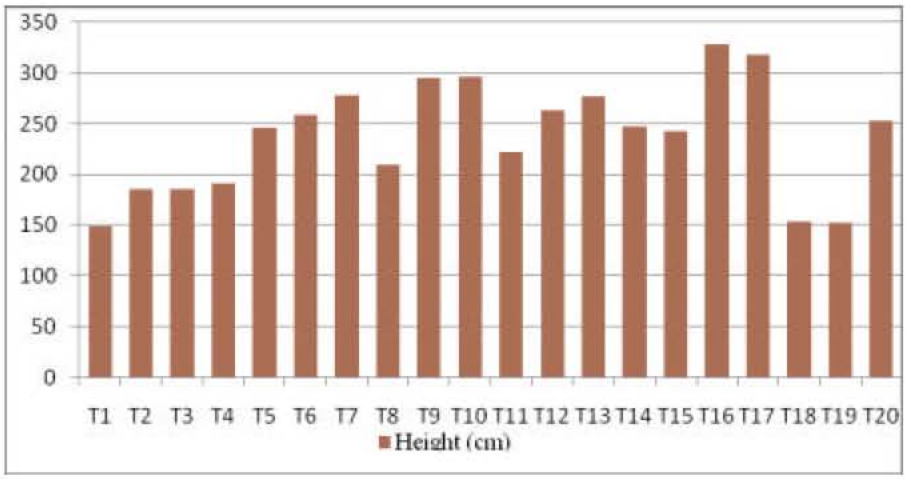

Fig. 4: Variation in plant height of different progenies

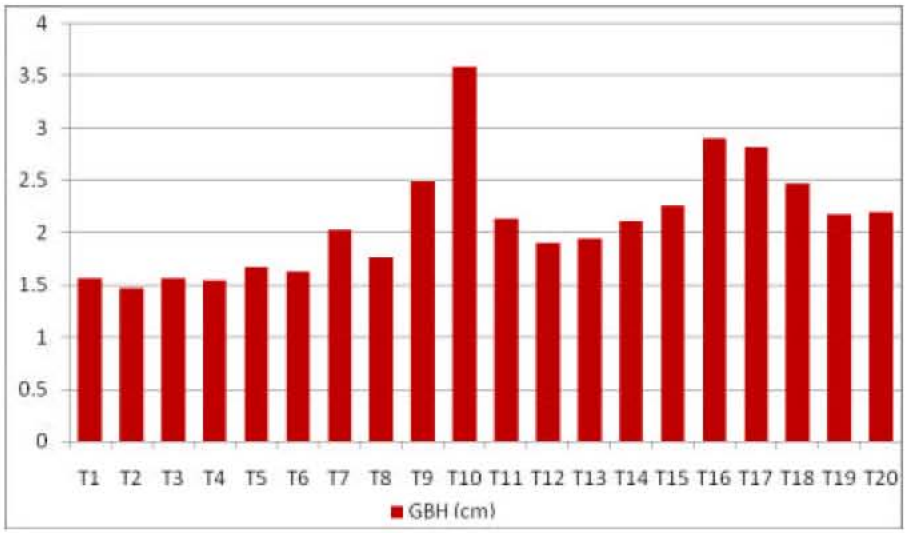

Fig. 5: Variation in GBH (girth at breast height) of different progenies

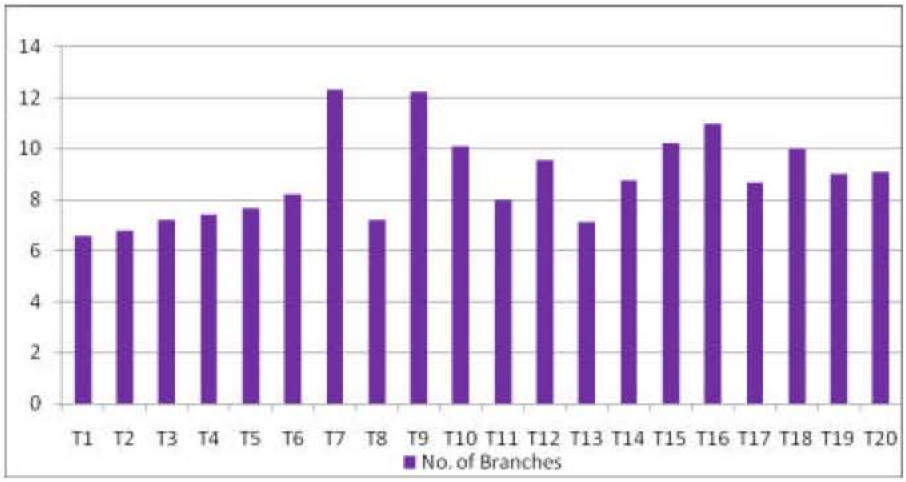

Fig. 6: Variation in oil content of different progenies

CONCLUSION

In the study, all the selected progenies are growing well in tropical climate of Madhya Pradesh, India. However, T16, T17, T10, T9, T7, T18 and T13 are performing better among different progenies. Performance evaluation of selected progenies will provide necessary and valuable information for establishing large scale plantations comprising of quality planting material. Being an agricultural country endowed with varied climates, nutrient-rich soil and ability to grow many different crops, India offers a great promise as a producer of surplus raw material for biodiesel production. In India the feasibility of producing biodiesel as diesel substitute can be significantly thought as there is a large patches of degraded forest land, unutilized public land and fallow lands of farmers, even rural areas that will be beneficial for overall economic growth. Indigenous production of Karanja oil will save foreign exchange worth of several million dollars and also generate employment opportunities in rural areas.

ACKNOWLEDGEMENT

The work was supported by a grant from the National Oilseeds and Vegetable Oils Development Board (NOVOD), Govt. of India, Ministry of Agriculture, New Delhi.

REFERENCES

1. Mandal, R., 2005. Energy-alternate solutions for India's needs: biodiesel. Adviser for the Planning Commission, Government of India.
2. GOI., 2009. Basic statistics on Indian petroleum and natural gas 2008-09. Ministry of petroleum and natural gas. Government of India, pp: 17.
3. Troup, 1921. The silviculture of Indian Tree, Volume IV, Family Leguminosae.
4. Scott, P.T., L. Pregelj, N. Chen, J.S. Hadler, M.A. Djordjevic and P.M. Gresshoff, 2008. *Pongamia pinnata*: An untapped resource for the biofuels industry of the future. Bioenerg. Res., 1: 2-11.
5. Duke, J.A., 1983. Handbook of Energy Crops, unpublished, Excerpt from the Internet., http:// www. hort. purdue.edu/ newcrop/ duke_energy/ Pongamia_ pinnata.html.
6. Bhat, G.S. and P.S. Chauhan, 2002. Provenance variation in seed and seedling traits of *Albizzia lebbek* Benth. J. Tree Scientists, 21: 52-57.
7. Zobel, B. and J. Talbert, 1984. Applied Forest Tree Improvement. John Wiley and Sons, New York.
8. Gutterman, Y., 1992. Maternal effects of seed during development. In: Fenner, M. Seeds: The Ecology of Regeneration in Plant Communities. CAB International, Wallingford, UK., pp: 27-59.
9. Divakara, B.N., A.S. Alur and S. Tripathi, 2010. Genetic variability and relationship of pod and seed traits in *Pongamia* pinnata (L.) Pierre., a potential agroforestry tree. Intl. J. Plant Production, 4(2): 129-141.
10. Sunil, N., V. Kumar, N. Sivaraj, C. Lavanya, R.B.N. Prasad, B.V.S.K. Rao and K.S. Varaprasad, 2010. Variability and divergence in *Pongamia pinnata* (L.) Pierre germplasm-a candidate tree for biodiesel. J. Bioenergy, 1(6): 382-391.
11. Mukta, N., I.Y.L.N. Murthy and P. Sripal, 2009. Variability assessment in *Pongamia pinnata* (L.) Pierre germplasm for biodiesel traits. J. Industrial Crops and Products, 29(2-3): 536-540.
12. Kaushik, N., S. Kumar, K. Kumar, R.S. Beniwal, N. Kaushik and S. Roy, 2007. Genetic variability and association studies in pod and seed traits of *Pongamia pinnata* (L.) Pierre in Haryana. J. India Genetic Resources and Crop Evolution, 54: 1827-1832.
13. Kesari, V., A. Krishnamachari and L. Rangan, 2008. Systematic characterisation and seed oil analysis in candidate plus trees of biodiesel plant, *Pongamia pinnata.* J. Ann. Appl. Biol., 152(1): 397-404.
14. Panse, V.G. and P.V. Sukhatme, 1961. Statistical Methods for Agricultural Workers. New Delhi: ICAR., pp: 381.
15. Mukta, N. and Y. Sreevalli, 2010. Propagation techniques, evaluation and improvement of the biodiesel plant, *Pongamia pinnata* (L.) Pierre-A review. J. Industrial Crops and Products, 31(1): 1-12.
16. Sahu, D.P., A. Subhashree and G.R. Rout, 2009. Inter and intra-population variability of *Pongamia pinnata:* a bioenergy legume tree. J. Plant Systematic and Evolution, 285(1-2): 121-125.
17. Pandey, A.K., P. Bhargava and A.K. Mandal, 2010. Performance evaluation of superior accessions of *Jatropha curcas* in tropical climate of Madhya Pradesh. J. Biofuels, 1(1): 131-139.
18. Sakia, S.P., B.S. Bhau, A. Rabha, S.P. Dutta, R.K. Chaudhari, M. Chetia, B.P. Mishra and P.B. Kanjilal, 2009. Study of accession source variation in morpho-physiological parameters and growth performance of *Jatropha curcas* Linn. Current Sci., 96(12): 1631-1636.