Performance evaluation of growth and carbon sequestration potential of Pongamia (*Pongamia pinnata* (L.) Pierre) germplasms

Abstract

Agroforestry has emerged as a powerful land management practise to address the shrinking land holdings, size and reduced productivity of the land with improved ecosystem services. In recent decades, evaluation of the germplasms, particularly in Agroforestry systems is gaining a lot of importance in tree improvement programmes. The genetic section involves the selection of desired attributes, such as stress tolerance, increased wood properties, pest & disease resistance, etc. Pongamia based agroforestry system not only helps to mitigate climate change, but it will also have a significant share in the global biofuel production. The study was conducted in the 'M' block of AICRP on Agroforestry unit, ZARS, UAS, GKVK, Bangalore, during January 2022 to June 2022. This research evaluates the growth (tree height, stem diameter and crown width in East-West & North-South directions) and carbon sequestration potential of eight Pongamia germplasms. These eight germplasms are established in 5 x 5 spacing of RCBD design in three replications. The results revealed that RAK-2015-10 performed better for height growth, stem diameter and crown spread (East-West and North-South directions) compared to other germplasms. Since the tree height and stem diameter positively correlate with volume and biomass accumulation, RAK-2015-10 has recorded the maximum volume and biomass accumulation among the other germplasms. .The findings suggest that the cultivation of RAK-2015-10 can improve yield significantly. and helps to mitigate climate change.

Keywords: Germplasm, Agroforestry, Carbon sequestration, Biomass and Biofuel

[reviewer margin notes: "space"; "significantly and help"]

INTRODUCTION

Agroforestry is frequently regarded as a viable way to mitigate climate change. Agroforestry systems retain carbon in the soils and woody biomass. The majority of agroforestry systems can store carbon, although this capacity may vary depending on the treespecies (Prasad *et al.,* 2012) and management practices adopted in agroforestry systems.   Pongamia (*Pongamia pinnata* (L.) Pierre) belongs to the family – Fabaceae and is endemic to the Indian subcontinent and South-East Asia. Pongamia is recognised as the best biofuel yielding species due to its high oil content in seed (27 to 39 percent). The presence of toxic and anti-nutritional substances like pongamol, karanjin and

[reviewer margin note: "Fu et al., 2021)"]

glabrin, render it inedible(Bala et al., 2011).

In particular, in a tree with the desired attributes in terms of optimum growth pattern, phenology and yield component distribution, the knowledge of variation would be beneficial for genetic selection. genotype

In the current scenario, the trapping of atmospheric CO_2 in long-lived carbon pools of plant biomass and soil is one of the most viable ways to deal with elevated CO_2 levels in the atmosphere. The natural process by which plants absorb CO_2 from the atmosphere through photosynthesis and store it for as long as the plants are alive is known as biological sequestration of carbon. More photosynthesis results in more CO_2 being transformed intobiomass, which reduces atmospheric carbon and sequesters it in above and below ground plant tissue, leading to the expansion of various portions of the plant (Chavan and Rasal, 2010). ✓

Since, Pongamia is an important biofuel yielding species, it will help in the sequestration of carbon by minimizing the dependency on conventional fuels as well plays a critical role in reducing the pollution load in the atmosphere by providing biofuel. So, the species gaining a lot of importance in (Degani et al, 2022) the field of tree improvement over some time to develop new lines, varieties and hybrids to obtain better gains in the growth. Germplasm selection is another way of screening the germplasms to select the better genotype to obtain the high yield.

The present study aims to estimate the growth and carbon sequestration potential in eight Pongamia germplasms located at the 'M' block in (AICRP) on Agroforestry unit, ZARS, UAS, Banaglore.

MATERIAL AND METHODS

The present study entitled **"Performance evaluation growth and carbon sequestration potential of Pongamia (*Pongamia pinnata* (L.) Pierre) germplasms"**was carried out at 'M' block, in All India Coordinated Research Project(AICRP) on Agroforestry unit, Zonal Agricultural Research Station (ZARS),Gandhi Krishi Vigyana Kendra (GKVK), University ofAgricultural Sciences, Bengaluru, Karnataka during January 2022 to July 2022. The experimental plot was established in July 2017 and consists of eight Pongamiagermplasms at 5X5 meters spacing. These eight Pongamia germplasms are aligned in a Randomized Complete Block Design (RCBD) with three replications and the experimental site comprises 140 trees. Details of the eight Pongamia germplasms are given in Table1.

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Table 1: Details of Pongamia germplasms

Treatment	Germplasm	Passport data	
		Germplasm collection	**Propagation material**
T₁	RAK-2015-01	MPKV, Rahuri	Clone
T₂	RAK-2015-02	MPKV, Rahuri	Clone
T₃	RAK-2015-03	MPKV, Rahuri	Clone

T$_4$	RAK-2015-04	MPKV, Rahuri	Clone
T$_5$	RAK-2015-07	MPKV, Rahuri	Clone
T$_6$	RAK-2015-08	MPKV, Rahuri	Clone
T$_7$	RAK-2015-09	MPKV, Rahuri	Clone
T$_8$	RAK-2015-10	MPKV, Rahuri	Clone

Growth parameters: The tree biomass was calculated by non-destructive method by taking the measurements of stem diameter and total height of the standing trees and then volume was calculated. The total tree height was measured with the help of a measuring stick from the ground level to the tip of the tree and expressed in meter. The stem diameter at breast height (1.37 m) from the ground level was measured with the help of measuring tape and expressed in centimeter (Chaturvedi and Khanna, 1981). The crown spread of the tree was measured in East-West and North-South directions with the help of measuring tape and usually expressed in meter (Jennings *et al.*, 1999). Then the tree volume was calculated with the following formula, given by Chaturvedi and Khanna, 1981 and expressed in cubic meter.

$$V = \frac{\Pi * D^2}{4} * h$$

Where 'D' is stem diameter at breast height (m), 'h' is height in (m), п is 3.142

Biomass: The tree above ground biomass was estimated by multiplying mean volume with specific wood density and expressed in kg tree^{-1} (Brown and Lugo, 1982).

Above ground biomass = Volume x Specific wood density.
V= Basal area x Height x Form Factor
Basal area= (πd^2)/ 4

Below ground biomass of Pongamia trees was calculated by multiplying 26 percent to the above ground biomass (Ravindranath and Ostwald, 2008). Usually expressed in kg ha^{-1}.

BGB = AGB X 0.26

Total biomass of Pongamia trees was calculated by adding above and below ground biomass. Usually total biomass is expressed in kg ha^{-1}.

TB = AGB + BGB

Carbon sequestration potential: Fixed carbon content in wood was determined by multiplying the total biomass with the dry weight of wood. The dry weight of Pongamia was taken as 45%. Usually expressed in kg ha^{-1} (Pearson *et al.*, 2005).

Fixed carbon = TB X 0.45

CO_2 is composed of one molecule of carbon and two molecules of oxygen. The atomic weight of carbon, oxygen and carbon dioxide is 12.001115, 15.9994 and 43.999915 respectively. The ratio of atomic weight of CO_2 to C is 3.6663. Therefore, to determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.6663. Usually expressed in kg ha^{-1}.

Carbon sequestration = Fixed carbon content in wood X 3.6663

Statistical Analysis: Experimental data obtained were subjected to statistical analysis adopting Fisher's method of 'analysis of variance' as out lined by Gomez and Gomez (1984). The level of significance used in 'F' test was given 5 per cent for agroforestry studies. Critical difference (CD) values are given in the table at 5 per cent level of significance for agroforestry studies, wherever the 'F' test was found significant.

RESULTS AND DISCUSSION

The tree growth parameters like tree height, tree diameter at breast height, and crown spread (East-West direction and North-South direction) were computed and the data is presented in the Tables 2 and 3. The results present inTable 2 sshows a significant variation in tree height among the eight different Pongamia germplasms over a period of six months, the total height of five years old plants was found maximum in **RAK-2015-10** (4.15 m) followed by **RAK-2015-07** (3.83 m) and **RAK-2015-01** (3.81 m). Minimum height growth performance was recorded in **RAK-2015-02** (3.10 m). Data presented in the Table 2, indicate the variation in the diameter at breast height (DBH) over a period of six months. Among the eight different Pongamia germplasms, the diameter of five year age plants was found maximum in **RAK-2015-10** (8.37 cm) followed by **RAK-2015-07** (7.67 cm) and **RAK-2015-01** (7.62 cm). The lower diameter at breast height was observed in **RAK-2015-02** (6.54 cm). Better performance of growth characteristics like height and stem diameter in **RAK-2015-10** may be due to the genotypic response and environmental factors of the germplasms. As a consequence of variation in the germplasm will contribute to increased biomass production which can be exploited for enhancing land productivity. This was also in accordance with the Whittet*et al*. (2016)

Table 2: Tree height (m) and stem Diameter at Breast Height (DBH) (cm) of Pongamia germplasms

Germplasm	Tree height(m)		DBH (cm)	
	January, 2022	June, 2022	January, 2022	June, 2022
RAK-2015-01	3.46	3.81	6.73	7.62
RAK-2015-02	2.87	3.10	5.96	6.54
RAK-2015-03	2.82	3.18	5.56	6.57
RAK-2015-04	3.16	3.59	6.83	7.53

RAK-2015-07	3.15	3.83	7.00	7.67
RAK-2015-08	3.08	3.32	6.74	7.41
RAK-2015-09	2.94	3.19	6.24	6.90
RAK-2015-10	3.65	4.15	7.74	8.37
S.Em ±	**0.15**	**0.22**	**0.42**	**0.51**
CD (p=0.05)	**0.47**	**0.68**	**NS**	**NS**
C.V (%)	**8.67**	**11.16**	**10.93**	**12.17**

*Significant at 5% level of significance   NS- non significant

The data presented in the Table 3, reveals the variation in the crown spread of east-west direction in an interval of six months. Among the eight different Pongamia germplasms, the crown spread of east-west direction was found maximum in **RAK-2015-10** (3.92m) followed by **RAK-2015-07** (3.51m) and **RAK-2015-01 (**3.44m**)**. The minimum crown spread was recorded in **RAK-2015-02** (3.06m).Among the eight different Pongamia germplasms, the significant variations were observed in crown spread (north- south) over a period of six months. After five years of planting the crown spread were found to be maximum in **RAK-2015-10** (4.15m) followed by **RAK-2015-07** (3.97m) and **RAK-2015-01 (**3.75m**)**. The minimum crown spread was recorded in **RAK-2015-02** (3.10m). The higher crown spread in **RAK-2015-10** might be due genomic response of the respective germplasm, easy availability of nutrients from the decomposition of litter and also from the mineralization.

Table 3: Canopy spread (m) of Pongamia germplasms

Germplasm	**East – West direction (m)**		**North – South direction (m)**	
	January, 2022	**June, 2022**	**January, 2022**	**June, 2022**
RAK-2015-01	2.95	3.44	3.25	3.75
RAK-2015-02	2.75	3.06	2.85	3.10
RAK-2015-03	2.47	3.11	2.77	3.19
RAK-2015-04	2.74	3.18	2.83	3.53
RAK-2015-07	3.02	3.51	2.87	3.97
RAK-2015-08	2.59	3.16	2.67	3.32
RAK-2015-09	2.75	3.11	2.48	3.19
RAK-2015-10	3.07	3.92	3.26	4.15
S.Em ±	**0.19**	**0.27**	**0.15**	**0.23**
CD (p=0.05)	**NS**	**NS**	**0.46**	**0.69**
C.V (%)	**11.78**	**13.87**	**9.13**	**11.10**

*Significant at 5% level of significance   NS- non significant

Biomass: The biomass is assessed based on the data of growth performance of *Pongamia pinnata viz.,* height (m), stem diameter or diameter at breast height (cm), volume (m^3), above ground biomass (kg ha^{-1}), below ground biomass (kg ha^{-1}) and total biomass (kg ha^{-1}). The tree growth increment parameters like volume (m^3 tree^{-1}& m^3 ha^{-1}), above ground biomass (kg ha^{-1}), below ground biomass (kg ha^{-1}) and total biomass (kg ha^{-1}) are presented in the Table 4 and 5. All the germplasms showed significant difference for volume per tree and volume per hectare in five years old plantation. Among

the eight different Pongamia germplasms, the volume per tree and volume per hectare were found to be maximum in **RAK-2015-10** ($0.0082 \, m^3 \, tree^{-1}$ and $3.272 \, m^3 \, ha^{-1}$) followed by **RAK-2015-07** ($0.0051 \, m^3 \, tree^{-1}$ and $2.041 \, m^3 \, ha^{-1}$) and **RAK-2015-01** ($0.0050 \, m^3 \, tree^{-1}$ and $1.994 \, m^3 \, ha^{-1}$). The lowest volume per tree was recorded in **RAK-2015-02** ($0.0031 \, m^3 \, tree^{-1}$ and $1.249 \, m^3 \, ha^{-1}$) (Table 4). Tree volume is the most important for estimation of biomass to estimate the degree of carbon sequestration by the trees. Volume to biomass is considered as the better estimation method of forest tree biomass. Similar results were also reported by Brown, 1997 and Bohre *et al*. (2014).

Different germplasms showed the significant influence on the above ground biomass, below ground biomass and total biomass (Table 5). Significantly maximum above ground biomass, below ground biomass and total biomass was recorded in **RAK-2015-10** ($1992 \, kg \, ha^{-1}$, $518 \, kg \, ha^{-1}$ and $2510 \, kg \, ha^{-1}$) followed by **RAK-2015-07** ($1243 \, kg \, ha^{-1}$, $323 \, kg \, ha^{-1}$ and $1566 \, kg \, ha^{-1}$) and **RAK-2015-01** ($1214 \, kg \, ha^{-1}$, $315 \, kg \, ha^{-1}$ and $1530 \, kg \, ha^{-1}$) respectively. The lower above ground biomass observed in **RAK-2015-02** ($761 \, kg \, ha^{-1}$, $197 \, kg \, ha^{-1}$ and $958 \, kg \, ha^{-1}$) (Table 5). Among the different germplasms **RAK-2015-10** found to have higher accumulation of above ground biomass, below ground biomass and total biomass, might be due to environmental factors and genotypic response of the germplasm. So, this variation in the germplasm in terms of above ground accumulation, below ground biomass and total biomass can be exploited for enhancing the land productivity. This was also in accordance with the findings of Bohre *et al*. (2014) and Singh and Pokhrial, 2000.

Table 4: Tree volume ($m^3 \, tree^{-1}$ & $m^3 \, ha^{-1}$) of Pongamia germplasms

Germplasm	Tree volume ($m^3 \, tree^{-1}$)		Tree volume ($m^3 \, ha^{-1}$)	
	January, 2022	June, 2022	January, 2022	June, 2022
RAK-2015-01	0.0039	0.0050	1.547	1.994
RAK-2015-02	0.0023	0.0031	0.933	1.249
RAK-2015-03	0.0023	0.0031	1.055	1.371
RAK-2015-04	0.0038	0.0049	1.511	1.951
RAK-2015-07	0.0039	0.0051	1.551	2.041
RAK-2015-08	0.0034	0.0046	1.353	1.840
RAK-2015-09	0.0034	0.0045	1.374	1.813
RAK-2015-10	0.0068	0.0082	2.725	3.272
S.Em ±	**0.0004**	**0.0005**	**0.148**	**0.205**
CD (p=0.05)	**0.0011**	**0.0016**	**0.449**	**0.623**
C.V (%)	**17.03**	**18.31**	**17.03**	**18.31**

*Significant at 5% level of significance.

Carbon Sequestration: The carbon sequestration is assessed based on the data of growth performance of *Pongamia pinnata viz.,* height (m), girth (m) or diameter at breast height (cm), volume (m^3) and biomass ($kg \, ha^{-1}$). The total carbon content ($kg \, ha^{-1}$) and carbon sequestration potential ($kg \, ha^{-1}$) are presented in Table 6. The data presented in the Table 6 reveals the significant variation in the accumulated carbon content and carbon sequestration potential of Pongamia. **RAK-2015-10** was found to have accumulated higher carbon content and carbon sequestration potential ($1129 \, kg \, ha^{-1}$ and $4142 \, kg \, ha^{-1}$) among the eight different Pongamia germplasms. Results also revealed that the lower carbon content and carbon sequestration potential was observed in **RAK-2015-02** ($431 \, kg \, ha^{-}$

[1] and 1582kg ha^{-1}). Assessment and adaptation of genotypic variation can play vital role in improving biomass production of agroforestry trees. It is also established that geography and ecosystem contribute to the species genetic constitution that results in the production of biomass variation within the same species (FAO, 1985). ✓

Table 5: Above ground biomass (kg ha^{-1}), below ground biomass (kg ha^{-1}) and total biomass (kg ha^{-1}) of Pongamia germplasms.

Germplasm	AGB (kg ha^{-1})		BGB (kg ha^{-1})		TB (kg ha^{-1})	
	January, 2022	June, 2022	January, 2022	June, 2022	January, 2022	June, 2022
RAK-2015-01	942	1214	245	315	1187	1530
RAK-2015-02	568	761	147	197	716	958
RAK-2015-03	642	835	167	217	809	1052
RAK-2015-04	920	1188	239	309	1159	1497
RAK-2015-07	944	1243	245	323	1190	1566
RAK-2015-08	824	1121	214	291	1038	1412
RAK-2015-09	837	1104	217	287	1054	1391
RAK-2015-10	1660	1992	431	518	2091	2510
S.Em ±	90	125	23	32	113	157
C. D (p=0.05)	273	379	71	98	345	478
C.V (%)	17	18	17	18	17	18

✓

*Significant at 5% level of significance

AGB-Above ground biomass   BGB- Below ground biomass   TB- Total biomass

Table 6: Total carbon content (kg ha^{-1}) and carbon sequestration potential (kg ha^{-1}) of Pongamia germplasms

Germplasm	Total carbon content (kg ha^{-1})		Carbon sequestration potential (kg ha^{-1})	
	January	June	January	June
RAK-2015-01	534	688	1959	2525
RAK-2015-02	322	431	1182	1582
RAK-2015-03	364	473	1336	1736
RAK-2015-04	521	673	1913	2470
RAK-2015-07	535	705	1964	2585
RAK-2015-08	467	635	1712	2330
RAK-2015-09	474	626	1740	2296
RAK-2015-10	941	1129	3450	4142
S.Em ±	51	70	187	260
C. D (p=0.05)	155	215	569	788
C.V (%)	17	18	17	18

*Significant at 5% level of significance.

CONCLUSION:

The study was conducted to assess the growth and carbon sequestration potential of eight Pongamia germplasms over six months after five years of planting. Study reveals that the height, stem diameterand crown spread in East-West and North-South directions were recorded maximum in RAK-2015-10. Since, the stem diameter and tree height growths are directly proportional to the volume increment and biomass accumulation, RAK-2015-10 has recorded the highest volume increment and biomass accumulation. The carbon sequestration potential found maximum in RAK-2015-10, when compared to other germplasms. Hence, expanding the planting of RAK-2015-10 can improve the yield significantly. In addition to this, managing more and more plantations of RAK-2015-10 helps to mitigate the climate change.

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