Carbon sequestration potential of different provenance of *Pongamia pinnata*in central India

ABSTRACT: -*Pongamia pinnata* is commonly known as Karanja is a moderate sized evergreen tree and bark is smooth, gray and thin. Pongamia starts flowering from 4^{th} to 7^{th} year of planting/germination. White and purplish flowers in auxiliary racemes appear in March-May and the pods ripen from December-March in the following year.The present investigation was conducted in different provenances of p. pinnata from the various agro-climatic zone of Madhya Pradesh were selected. *Pongamia pinnata* is a deciduous tree species and one of the widely available trees found in the Madhya Pradesh. Studying about this particular provenance is valuable in various aspects particularly estimating the carbon sequestration potential and extraction of biodiesel from the seed of this tree to be an input for the climate change mitigation activities taking place in India and in the world at large, since climate change is the worldwide issue.It was observed from the result during the 10^{th} year of plantation (2015) different provenances showed the significant influence on the above ground biomass, Significantly maximum above ground biomass (1.38 t ha^{-1}) was recorded in provenance T_{13} (Nagod road, Satna), whereas minimum (0.41 t ha^{-1}) was recorded in T_{21} (KrishiVigyan Kendra, Seoni).Different provenances observed significant among themselves for carbon sequestration potential at age of ten year old . Significantly maximum carbon sequestration potential (3.39 t/ha) was recorded in provenance T_{13} (Nagod road, Satna), whereas minimum carbon sequestration potential (0.97 t/ha) was recorded in T_{21} (KVK, Seoni).

Keywords: - *Carbon Sequestration, Provenance, Pongamia pinnata.*

INTRODUCTION

Currently, global warming is more certain and alarming than ever. Most of the observed increase in global average temperatures is due to the observed steady increase of CO_2 in our atmosphere, i.e. from 280 parts per million (ppm) in 1850 up to 394 ppm in 2012 (NOAA, 2012). At the 16^{th} session of the parties held in 2010, to the UNFCCC agreed that future global warming should be limited below 2°C relative to the pre-industrial temperature level (UNFCCC, 2011). The amount of carbon sequestered and stored in forest varies greatly based on a large number of factors, including the type of forest, its net primary production, the age of the forest, and its overall composition (Millard, 2007). Carbon storage in forest ecosystems involves numerous components including biomass carbon and soil carbon.

Carbon management is a serious concern confronting the world today. A number of summits have been organized on this subject ranging from the Stockholm to Kyoto protocol. The current level of carbon in the atmosphere is about 390 ppm. It estimated that if the carbon increase in the atmosphere at the present rate and no positive efforts are pursued, the level of carbon in the 3 atmosphere would go up 800-1000 ppm by the end of year, 2100, which may create havoc for all living creatures on earth.

The plantation technologies plays an important role to removed CO_2 from the atmosphere and stored in and on the surface of the earth assuming the given amount of CO_2 will remain stored in and on the same stable way as reserve of the oil, natural gas or coal beneath the ground for centuries to come. The phenomenon of CO_2 removal from the atmosphere and its storage in plant tissue or biomass is known as carbon sequestration. Selection of ideal species for plantation technology is very important step for restoration of reduced ecosystem. Plantation technology can reduce the pressure on existing natural forests by providing fuel, fodder, timber and wood products directly to the surrounding people on the one hand and on the other it may provide many indirect environmental benefits such as soil and water conservation, biodiversity conservation, soil nutrients enrichment *etc.*

Plants take up carbon dioxide from the atmosphere and incorporate emitted back to the atmosphere but what is left-the live and the dead plant parts, above and below ground, make up organic carbon reservoir (Trumper *et al.,* 2009). Therefore, growing trees will reduce the concentration of CO2 in atmosphere by its accumulation in the form of biomass. As the trees grow, their biomass increases (Mathews *et al.,* 2000) resulting in growth of different parts. The biomass or primary production of the plants depends on their ability to fix carbon from the atmosphere. It is in the form of fixed biomass through photosynthesis during their growth processes, thereby acting as carbon sink.

Because of importance of carbon pools in tropical forests and in the plantation systems, many organizations around the world carried out studies related to forest biomass and carbon storage in recent decades. Many workers studied biomass production of tropical forests and different species by actual harvest at a predetermined age and allometric equations relating biomass with one or more tree dimensions (Kira *et al.,* 1964; Hozumi *et al.,* 1969; Rai, 1984;

Sharma and Srivastava, 1984). The results might be quite different, if the age of assessments had changed. Generation of allometric equations that involve felling of trees is impracticable in the current scenario of climate change. Thus, it is required to adopt non harvest techniques and acceptable level of accuracy.

Karanja is one of the fast growing leguminous trees that have a high potential for oil seed production, with the ability to grow on marginal lands which supports its cultivation as a potential biofuel crop for biodiesel industry. *Pongamia pinnata* is a medium sized semi- evergreen drought resistant tree and the seeds yield non edible Pongamia oil, which is used for tanning and soap making and also as biodiesel. It is an excellent coppicer and is frequently pollard for green manure. High quality oil recovery of karanja oil will increase foreign exchange worth of several million dollars in addition to generating employment opportunities in rural areas (Sahoo *et al.*, 2011). Self-reliance in energy is vital for overall economic development of India and other developing countries. The need to search for alternative source of energy which is renewable, safe and non-polluting assumes top priority in view of the uncertain supplies & frequent price hike of fossil fuels in the international market. Since the recent huge demand for oil and fossil fuel reserves is largely dependent on non-renewable energy resources, so there is need in promotion of tree-borne oil seed species as an alternate source of energy.

India has a vast tract of wastelands and degraded lands, mostly in areas with adverse agro climatic conditions, for growth traits and seed yield where hardy tree borne oil seed species like *Pongamia pinnata* can be grown easily. Thus looking to its wide adaptability it is pertinent to study the extent and patterns of variation for growth and yield traits and their inter-relationship among themselves to plan proper strategy for its genetic improvement on which information are meagre. In this context, the genetic potential of the Pongamia candidate plus trees (cpt) among the naturally available population needs evaluation with respect to their pod and seed characteristics and seed oil content. The variability in the pod and seed characteristics could be linked to the genetic potential of a genotype. A few studies have been conducted on seed traits of *Albizzia lebbek* (Bhat and Chauhan, 2002) and *Calophyllumin ophyllum* (Hathurusingha *et al.*, 2010) in relation to their provenance variation.

During the study the different provenances of p. pinnata from the various agro-climatic zone of Madhya Pradesh were selected.*Pongamia pinnata* is a deciduous tree species and one of the widely available trees found in the Madhya Pradesh. Studying about this particular provenance is valuable in various aspects particularly estimating the carbon sequestration potential and extraction of biodiesel from the seed of this tree to be an input for the climate change mitigation activities taking place in India and in the world at large, since climate change is the worldwide issue.

MATERIAL AND METHODS

Experimental details:

Design	–	RBD
Replication	–	Three
No. of Treatments	–	22 Provenances
Number of plants/plot	–	09
Spacing	–	5m x 5m
Total Number of seedling planted	–	594
Total area under plantation	–	14850 sqm (or 1.4850 ha.)
Year of Plantation	–	2005
Year of Experimentation	–	2015

Provenance Details

T1 - Bandole-1 Seoni	T12 - Lalpur, Nagod Road, Satna
T2 - Kosamghat, Jabalpur	T13 - Nagod Road, Satna
T3 - Bahoripar, Bargi, Jabalpur	T14 - 4th mile Mandla
T4 - Kailwas, Barha, Jabalpur	T15 - Kushmeli Road, Amarwada, Chhindwara
T5 - TFRI, Gour river, Jabalpur	T16 - TFRI, Garden, Jabalpur
T6 - Kalpi Depot, Mandla	T17 - Lalpur - II Nagod Road, Satna
T7 - Cantt Area, Jabalpur	T18 - Circular Road, Chhindwara
T8 - Bandole – 2, Seoni	T19 - Jhighri, Katni
T9 - Maihar – I, Maihar	T20 - Khajurahoo Road, Panna
T10 - Bargi (JN-4), Jabalpur	T21 - KrishiVigyan Kendra, Seoni
T11 - Maihar – II, Maihar	T22 - Nagod, Satna

Methodology for Growth Parameters

Tree Height (m)

The total heights of individual standing trees in each stand were measured from the ground level to the tip of the leading shoot with the help of a 30 m long measuring tape. It is expressed in meter.

Diameter at Breast Height (cm)

For determination of Diameter at breast height (dbh), Circumference (C) of individual standing trees were measured with the help of measuring tape at 1.37 m height from ground level and circumference was convert in to dbh by using following relation (dbh=C/3.14). It is expressed in cm.

Basal diameter (cm)

For the measurement of basal diameter, Circumference(C) of individual standing trees were measured with the help of measuring tape at 10 cm height from ground level and circumference was convert in to basal diameter by using following relation (BD=C/3.14). It is expressed in cm.

Basal area (m^2)

Basal area of selected trees in a stand was calculated by using following formula:

$$\text{Basal area} = 0.00007854 \times (\text{dbh})^2$$

Methodology for Carbon sequestration and other parameters

Pod size

(a) Pod Length

The pod length of the tree from each plot was measured with the help of Vernier calliper and then average seed length was tabulated.

(b) Pod Width

The pod width of the tree was measured by the Vernier callipers in millimeter taken from each treatment and the width of the seed was calculated.

Seed size

(a) Seed Length (mm)

The seed length of the tree from each plot was measured with the help of Vernier calliper and then average seed length was tabulated.

(b) Width (mm)

The seed width of the tree was measured by the Vernier callipers in millimeter taken from each treatment and the width of the seed was calculated.

Fresh weight of wood (gm)

When a tree is first felled, it is considered to be in the green state, and contains a very large amount of moisture. This moisture exists in two different forms: as free water that is contained as liquid in the pores or vessels of the wood itself, and as bound water that is trapped within the cell walls.

Oven dry weight of wood (gm)

Oven dry weight is the quasi-constant weight attained by wood samples dried at 80 0C.

Moisture content (%)

Moisture content was determined by taking fresh weight of wood samples. Oven dry weight of samples was determined at 80 ˚C in hot air oven for a period until a constant weight of wood samples achieved. The relation used is as follows:

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight (g)} - \text{Oven dry weight (g)}}{\text{Fresh weight (g)}} \times 100$$

Tree volume (m^3 ha^{-1})

The above ground volume of selected standing trees was calculated by using basal area and tree height in the following relation:

$$\text{Volume of standing tree} = \text{Basal area} \times \text{Tree height}$$

Specific gravity

[Negi *et al.*, 2003 Mani *et al.*, 2007 and Jana *et al.*, 2009]

Specific gravity was calculated by using the formula:

$$\text{Specific gravity} = \frac{\text{Oven dry weight of wood sample}}{\text{Volume of that wood sample}}$$

Above Ground Biomass of trees (t ha^{-1})

[Negi *et al*., 2003 Mani *et al*., 2007 and Jana et al., 2009]

Stand biomass (above ground) of trees was estimated by using formula i.e.

$$\text{Biomass (kg/tree)} = \text{Volume of tree} \times \text{specific gravity}$$

Ash content (%) [Jana *et al*., 2009]

Ash content was determined by calculating the ash content of wood samples of each pruning intensities. For this, the oven dried wood samples were completely burned to get ash. The relation used for determination of ash content is as follows:

$$\text{Ash content (\%)} = \frac{\text{Weight of ash}}{\text{Oven dry weight}} \times 100$$

Fixed carbon stock (t/ha) [Ganeshiah *et al.*, 2003]

Fixed carbon mainly contributes to carbon storage. It is determined by detecting moisture content % and ash content % from 100 as percentage and remainder is assumed as the pure or fixed carbon. The relation was used as follows:

$$\text{Fixed carbon (\%)} = 100 - (\text{Ash content\%} + \text{Moisture content \%})$$

Then the fixed carbon percentage is converted in fixed carbon stock (t/ha) by multiplying with tree biomass.

Carbon sequestration (t/ha) [Jana *et al.*, 2009]

The total biomass carbon storage was calculated by using the following formula:

$$\text{Carbon sequestration (tone C ha}^{-1}\text{)} = \text{biomass of tree x fixed carbon (\%)}$$

Determination of weight of CO_2 sequestered in the tree (kg/tree)

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 by multiply the weight of carbon in the tree by 3.6663.

RESULT

Aboveground biomass and Carbon sequestration potential in different provenances *Pongamia pinnata* at age of 10 year old

Fresh weight of wood samples (gm)

It was observed from the result during the 10th year (2015) different provenances showed the non-significant influence on the fresh weight of wood (Table 01). Therefore the result was not discussed.

Table 01: Fresh weights of wood, Oven dry Weight of wood samples and Moisture content% of different provenances.

Treatments (provenances)	**Fresh weight of wood samples (gm)**	**Oven dry Weight of wood samples (gm)**	**Moisture content %**
T_1 - Bandole-1 Seoni	52	38	35
T_2 - Kosamghat, Jabalpur	50	38	34
T_3 - Bahoripar, Bargi, Jabalpur	51	39	32
T_4 - Kailwas, Barha, Jabalpur	49	37	32
T_5 - TFRI, Gour river, Jabalpur	52	41	27
T_6 - Kalpi Depot, Mandla	51	38	32
T_7 - Cantt Area, Jabalpur	48	36	32
T_8 - Bandole – 2, Seoni	50	39	30
T_9 - Maihar – I, Maihar	51	39	32
T_{10} - Bargi (JN-4), Jabalpur	51	38	33
T_{11} - Maihar – II, Maihar	50	38	32
T_{12} - Lalpur, Nagod Road, Satna	51	39	32
T_{13} - Nagod Road, Satna	49	38	32
T_{14} - 4th mile Mandla,	51	39	32
T_{15} - Kushmeli Road, Amarwada, Chhindwara	49	36	36
T_{16} - TFRI, Garden, Jabalpur	52	39	32
T_{17} - Lalpur - II Nagod Road, Satna	51	39	32
T_{18} - Circular Road, Chhindwara	53	40	32
T_{19} - Jhighri, Katni	52	40	28
T_{20} - Khajurahoo Road, Panna	53	40	32
T_{21} - Krishi Vigyan Kendra, Seoni	51	39	32
T_{22} - Nagod, Satna	50	38	32
SEm±	1.25	1.61	4.87
CD at 5%	NS	NS	NS

Oven dry Weight of wood samples (gm)

It was observed from the result during the 10th year (2015) different provenances showed the non-significant influence on the oven dry weight of wood (Table 01). Therefore the result was not discussed.

Moisture content %

It was observed from the result during the 10th year (2015) different provenances showed the non-significant influence on the moisture content percentage (Table 01). Therefore the result was not discussed.

Tree volume (m^3 ha^{-1})

Different provenances observed significant among themselves for tree height at age of ten year old (Table 02). Significantly maximum tree volume (22.92 m^3 ha^{-1}) was recorded in provenance T_{13} (Nagod road, Satna) followed by T14 i.e., 4th mile Mandla (17.26 m^3 $ha^{-1)}$, T16 i.e., TFRI garden Jabalpur (16.34 m^3 ha^{-1}), T18 i.e., Circular road Chhindwara (16.27 m^3 $ha^{-1)}$, whereas minimum Tree volume (7.04 m^3 ha^{-1}) was recorded in T_{21} (KVK, Seoni).

Table 02: Tree volume and Specific gravityof different provenances.

Treatments (provenances)	**Tree volume (m^3 ha^{-1})**	**Specific gravity**
T_1 - Bandole-1 Seoni	9.84	0.606
T_2 - Kosamghat, Jabalpur	15.08	0.608
T_3 - Bahoripar, Bargi, Jabalpur	12.26	0.598
T_4 - Kailwas, Barha, Jabalpur	8.41	0.601
T_5 - TFRI, Gour river, Jabalpur	14.97	0.616
T_6 - Kalpi Depot, Mandla	15.64	0.618
T_7 - Cantt Area, Jabalpur	10.91	0.605
T_8 - Bandole – 2, Seoni	12.57	0.602
T_9 - Maihar – I, Maihar	13.44	0.586
T_{10} - Bargi (JN-4), Jabalpur	15.20	0.602
T_{11} - Maihar – II, Maihar	15.17	0.592
T_{12} - Lalpur, Nagod Road, Satna	11.66	0.628
T_{13} - Nagod Road, Satna	22.92	0.614
T_{14} - 4th mile Mandla,	17.26	0.585
T_{15} - Kushmeli Road, Amarwada, Chhindwara	11.39	0.603
T_{16} - TFRI, Garden, Jabalpur	16.34	0.596
T_{17} - Lalpur - II Nagod Road, Satna	15.98	0.603
T_{18} - Circular Road, Chhindwara	16.27	0.604
T_{19} - Jhighri, Katni	10.26	0.600
T_{20} - Khajurahoo Road, Panna	11.25	0.599
T_{21} - Krishi Vigyan Kendra, Seoni	7.04	0.573
T_{22} - Nagod, Satna	11.61	0.603
SEm±	3.91	0.03
CD at 5%	11.19	0.09

Specific gravity

Different provenances observed significant among themselves for specific gravity at age of ten year old plantation (Table 02), Significantly maximum specific gravity (0.628) was recorded in provenance T_{12} (Lalpur, Nagod Road Satna), followed by T6 i.e., Kalpi depot Mandla (0.618), T5 i.e., TFRI Gour river Jabalpur (0.616) whereas minimum specific gravity 0.573 was recorded in T_{21} i.e., KVK, Seoni.

Above ground biomass (kg ha^{-1})

It was observed from the result during the 10th year of plantation (2015) different provenances showed the significant influence on the above ground biomass (Table 03), Significantly maximum above ground biomass (1.38 t ha^{-1}) was recorded in provenance T_{13} (Nagod road, Satna), whereas minimum (0.41 t ha^{-1}) was recorded in T_{21} (KrishiVigyan Kendra, Seoni).

Table 03: Above ground biomass of different provenances.

Treatments (provenances)	**Above ground biomass (t ha^{-1})**	**Fixedcarbon stock(t/ha)**	**Carbon sequestration potential (t/ha)**
T_1 - Bandole-1 Seoni	0.61	0.45	1.61
T_2 - Kosamghat, Jabalpur	0.90	0.69	2.49
T_3 - Bahoripar, Bargi, Jabalpur	0.71	0.66	2.36
T_4 - Kailwas, Barha, Jabalpur	0.51	0.34	1.23
T_5 - TFRI, Gour river, Jabalpur	0.94	0.62	2.22
T_6 - Kalpi Depot, Mandla	0.97	0.77	2.78
T_7 - Cantt Area, Jabalpur	0.66	0.61	2.19
T_8 - Bandole – 2, Seoni	0.76	0.51	1.83
T_9 - Maihar – I, Maihar	0.77	0.46	1.66
T_{10} - Bargi (JN-4), Jabalpur	0.92	0.56	2.01
T_{11} - Maihar – II, Maihar	0.88	0.57	2.06
T_{12} - Lalpur, Nagod Road, Satna	0.72	0.48	1.72
T_{13} - Nagod Road, Satna	1.38	0.94	3.39
T_{14} - 4th mile Mandla,	1.00	0.66	2.37
T_{15} - Kushmeli Road, Amarwada, Chhindwara	0.69	0.65	2.33
T_{16} - TFRI, Garden, Jabalpur	0.98	0.77	2.78
T_{17} - Lalpur - II Nagod Road, Satna	0.96	0.69	2.48
T_{18} - Circular Road, Chhindwara	0.98	0.55	1.97
T_{19} - Jhighri, Katni	0.62	0.43	1.55
T_{20} - Khajurahoo Road, Panna	0.69	0.55	1.96
T_{21} - Krishi Vigyan Kendra, Seoni	0.41	0.27	0.97
T_{22} - Nagod, Satna	0.70	0.44	1.60

SEm±	0.23	0.13	0.48
CD at 5%	0.67	0.38	1.36

Fixed carbon stock(t/ha)

It was observed from the result during the 10th year of plantation (2015) different provenances showed the significant influence on the fixed carbon stock (Table 03), Significantly maximum fixed carbon stock (0.94 t/ha) was recorded in provenance T_{13} (Nagod Road, Satna), whereas minimum fixed carbon stock (0.27 t/ha) was recorded in T_{21} (Krishi Vigyan Kendra, Seoni).

Carbon sequestration potential (t/ha)

Different provenances observed significant among themselves for carbon sequestration potential at age of ten year old (Table 03). Significantly maximum carbon sequestration potential (3.39 t/ha) was recorded in provenance T_{13} (Nagod road, Satna), whereas minimum carbon sequestration potential (0.97 t/ha) was recorded in T_{21} (KVK, Seoni).

DISCUSSION

Tall trees have high woody biomass, support many leaves and increase carbon fixation which can ultimately sequestrate more of carbon and act as the sink of carbon for long time. Therefore, helps in mitigating greenhouse effect and climate change. In the present study the maximum height was observed for *Pongamia pinnata* in T_{13} i.e., Nagod road, Satna that sequester more carbon than other provenance. These results are in conformity with that of Kraenz *et al* (2003) who have also proved that tall trees have capability of increasing more carbon fixation which directly sequester more carbon. Tree volume is an important for assessment of standing biomass to estimate the degree of carbon sequestration by the trees. Volume to biomass method is considered as the better estimation method of forest tree biomass. (Brown *et al.*, 1997).Carbon sequestration can be defined as the removal of $CO_2$from atmosphere (source) in to green plants (sink) where it can be stored indefinitely. The maximum amount of Carbon storage in the present investigation was found in the T13 i.e., Nagod road, Satna with a value of 3.39 t/ha whereas minimum carbon storage was found T21 i.e., Krishi Vigyan Kendra, Seoni with a value of 0.97 t/ha.

CONCLUSION

Carbon sequestration through above mentioned provenances have potential to play important role in ameliorating global environment problems such as atmospheric accumulation of greenhouse gases (GHGs) and climate change. Therefore plantation of such superior provenance should be implemented and measures should be taken to protected the sink of carbon and mitigate the greenhouse effect through carbon storage.

REFFERENCE

Bhat GS and Chauhan PS. 2002.Provenance variations in seed and seedling traits of *Albizzia lebbek Benth*. Journal of Tree Science 21: 52-57.

Brown S. 1997. Estimating biomass and biomass change of tropical forests. A premier FAO forestry paper, FAO, Rome.pp 134.

Ganeshaiah KN, Barve N, Nath N, Chandrashekara K, Swamy M and Shaanker RU. 2003. Carbon allocation in different components of some tree species of India: A new approach for carbon estimation. Current Science, 85(11): 1528-1531.

Hathurusingha S, Ashwath N, Midmore DJ. 2010. Provenance variations in seed related characters, oil content of *Calophyllumino phyllum* L. in northern Australia and Srilanka. New For. 41: 89-94.

Hozumi K, Yoda K and Kira T. 1969.Production ecology of tropical rain forests in southern western Combodia.II-Photosynthetic prodctuin in evergreen seasonal forests, Nature and life in South East Asia, vol. 6, pp. 57-81.

Jana BK, Biswas S, Majumder M, Roy PK and Mazumdar A. 2009.Carbon sequestration rate and above ground biomass carbon potential of four young species. Journal of Ecology and Natural Environment, 1(2): 15-24.

Kraenzel M, Castillo A, Moore T and Potvin. 2003. Carbon storage of harvest age teak plantation, Panama. Forest Ecology and Management, 173(1/3): 213-225.

Millard P, Sommerkorn M and Grelet G. 2007. Environmental Change and Carbon Limitation in Trees: A Biochemical, Ecophysiological and Ecosystem Appraisal. New Phytologist, 175(1): 11-28.

Negi JDS and Chauhan PS. 2002. Greenhouse gases mitigation potential by sal (*Shorea robusta*) forests in doon valley. Indian forester, 128(7): 771-778.

Negi JDS and Chauhan PS. 2002. Greenhouse gases mitigation potential by sal (*Shorea robusta*) forests in doon valley. Indian forester, 128(7): 771-778.

NOAA. 2012. National Oceanic and Atmospheric Administration. (www.esrl.noaa.gov/ gmd/ccgg/trends/) Rajput SS, Shukla NK and VK Gupta, 1985.Specific gravity of Indian timbers. Journal of Timber Development Association of India, XXXI(3), 12-41.

Rai SN. 1984. Above ground biomass in tropical rain forests of Western Ghats, India. Indian Forester, volume 110, no. 8, pp. 754-764.

Ravindranath NH, Murthy IK, Chaturvedi R, Andrasko K and Sathaye J. 1997. Carbon forestry economic mitigation potential in India, by land classification.12 (6): pp 1027-1050.

Sahoo DP, Rout GR, Das S, Subhashree A and Mahapatra AK. 2011. Genotypic Variability and Correlation Studies in Pod and Seed Characteristics of *Pongamia pinnata* (L.) Pierre in Orissa, India.International Journal of Forestry Research.Volume 2011, Article ID 728985, 6 p.

Sharma SC and Srivastava VK. 1984. Biomass production in an age series of *Pinus patula* plantation in Tamil Nadu. Indian Forester, volume 110, no. 9, pp. 915-930.

Trumper K, Bertzky M, Dickson B, Heijden VDG, Jenkins M and Manning P. 2009. The Nature Fix? The role of ecosystems in climate mitigation.A UNEP rapid response assessment. United Nations Environment Programme, UNEP. WCMC. Cambridge, UK. Pp. 978-982.

UNFCCC. 2011. Status of Ratification of the Kyoto Protocol.