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3 authors:

Pradip Kumar Sarkar
ICAR Research Complex for Eastern Region

Bikash Das
Indian Council of Agricultural Research

Bhagwati Prasad Bhatt
NRM Division, KAB-II, Pusa, New Delhi-110012

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BAKAIN (*Melia azedarach* L.): A PROMISING AGROFORESTRY SPECIES FOR IMPROVING LIVELIHOOD TO FARMERS OF EASTERN PLATEAU AND HILL REGION OF INDIA

PRADIP KUMAR SARKAR[1]*, BIKASH DAS[1] AND B. P. BHATT[2]
[1]ICAR Research Complex for Eastern Region,
Research Centre, Plandu, Ranchi - 834 010, Jharkhand, INDIA
[2]ICAR Research Complex for Eastern Region, Patna - 800 014, Bihar, INDIA
e-mail: pradipsarkar.tripura@gmail.com

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***Corresponding author**

ABSTRACT

Bakain (*Melia azedarach*) is a fast growing species which is evident from high mean values of diameter at breast height (29.90 ± 2.24 cm), height (9.0 ± 2.71 m) and volume (0.63 ± 0.09 m^3 $tree^{-1}$) of 10 years old trees. It produced 3.19 ± 0.90 t ha^{-1} of leaves which contain 12.10 ± 2.21 % of crude protein. Farmers can earn Rs. 600-800 from sale of 6-8 years old tree. High carbon sequestration potential (10.72 ± 2.11 Mg C ha^{-1}) establishes its role in improvement of environmental health. Studies on soil properties under this agroforestry system (AFS) indicated significant increase in soil pH and electrical conductivity under ten years old tree indicating its usefulness in reclamation of acid soils. Moreover, significant decrease in available nitrogen and potassium in soil at 0-15 cm depth indicated the need for nutrient replenishment in topsoil for maintaining fertility under plantations. A method of matrix ranking of tree species, on the basis of farmers' preference taking a set of all possible uses into consideration, was developed and ranking of 5 selected forest tree species was done. Based on ranking, bakain was found most preferred by the farmers. Hence, bakain based AFS can be recommended and promoted as an important means of livelihood improvement of native communities.

INTRODUCTION

In India, rural communities form 68.84 % of the total population (Census of India, 2011), majority of which are mainly dependent on agriculture as a source of livelihood as well as income. The agrarian scenario of the eastern Plateau and Hill region of India is rainfed where rice based monocropping is the prevalent practice (Gulati and Rai, 2014; Das *et al.,* 2017). The soils of the region are low in organic carbon and available phosphorus content with deficiency of micronutrients like Boron and Zinc. Under these conditions, the productivity of agricultural crops are low leading to low profitability of upland agriculture under this region (Dey and Sarkar, 2011). At many places, the rural and the tribal farmers are partially depend on forest as a major source for fuelwood, fodder, timber, food, fruit and other Non Timber Forest Products (NTFPs) (Peters, 1994; Cunningham, 1996). But most of the time, agroforestry systems (AFS) play important role under rainfed condition in ensuring livelihood security of tribal farmers of eastern Plateau and Hill region. Among many such prevailing agroforestry systems *viz.,* Agri-horticultural system (fruit trees like Mango, Guava, Litchi, Jamun, *etc.*), agrisilvipastoral system (trees dominated by Gamhar, Teak, Eucalyptus, *etc.*) *etc.*, bakain (*Melia azedarach*) based agroforestry system could hardly draw any attention or interest of the farmers. This species, thus is being found to grow along boundaries or in homegarden on areas as small as negligible. The species has the potential to not only can improve environmental health but also to provide livelihood security to the farmers of the region because of its multiple uses like timber, fuelwood, fodder, *etc.* The fuelwood of this species has been reported to have as high calorific value as 5100 kcal kg^{-1} (Orwa *et al.,* 2009 and Sharma and Paul, 2013). There is very scarce information available on the species and it's socio-economic and environmental values were hardly given any importance while comparing with the other agroforestry species. Thus, keeping in view the unique condition of this region and the potential of this species, a study was carried out at Indian Council of Agricultural Research - Research Complex for Eastern Region, Research Centre, Ranchi as well as farmer's fields of four villages of Ranchi district of Jharkhand (*viz.,* Hundru, Chhotaghagra, Plandu and Ormanjhi), India to evaluate the system considering the tree canopy, plant growth and development parameters, carbon sequestration potential, changes in soil properties, fuelwood and fodder availability, market value of timber and fuelwood, and preferences of the species by the farmers. This study was also carried out to sort out the best species for this region based on it's growth potential, quick and high revenue generation, fodder availability, carbon sequestration potential and preferences of species by the farmers based on some most important criteria.

MATERIALS AND METHODS

Study site

Data were collected from the research farm of ICAR Research Complex for Eastern Region, Research Centre, Ranchi, Jharkhand, India (Table 1) and from farmers' fields of four villages of Ranchi district of Jharkhand (*viz.,* Hundru, Chhotaghagra, Plandu and Ormanjhi), India.

Research farm

From the research farm, a comparative study on growth performances of 10 years old plantation of fifteen different multipurpose tree species (Table 1) was carried out. Based on the volume thus estimated the best species of the region was sorted out which not only can change the livelihood scenario of the rural communities but also hold high potential to mitigate climate change through carbon sequestration.

Primary data on diameter at breast height (DBH) in cm, area coverage (m^2 or in hectare), Tree height (in meter), Crown length (in meter), Canopy spread area (in m^2), Number of leaves per tree (considering number of leaves per branch and number of branches per tree), Leaf length and width (in centimeter), Leaf area in cm^2 (Vyas *et al.*, 2010); Zhang and Liu, 2010), Leaf Area Index (Moser *et al.,* 2007), Light intensity (in kLUX) for measuring PAR (Photosynthetically Active Radiation) in μ mol m^{-2} s^{-1} (Abajingin and Ajayi, 2015) *etc*., were recorded. Leaf area was measured to the nearest millimeter of maximum leaf length (L) from lamina tip to the point of petiole intersection along the midrib and width (W) at the widest point perpendicular to the mid rib were carried out during the same day of detachment of leaves from the trees. The leaf area was calculated as follows (Zhang and Liu, 2010):

Leaf area of leaf as elliptical shape (LA_1) = 0.78 x Length x breadth .... (i)

Leaf area of leaf as triangular shape (LA_2) = 0.50 x Length x breadth .... (ii)

Hence, Actual leaf area (LA) = [(i) + (ii)]/2

Specific leaf area (SLA) was taken as the ratio of leaf area to dry mass (Vile *et al.,* 2005). Leaf area index (LAI) is a dimensionless quantity that characterizes plant canopies. It was measured as the one-sided green leaf area per unit ground surface area (Watson, 1947).

The plant is largely utilized by the tribal farmers for fodder purpose, particularly for small ruminants like goats. The quantity of dry leaves (t ha^{-1}) as fodder from 10 years old bakain tree was estimated during the study followed by its dry matter content (% of fresh leaf biomass) and crude protein (%) (Cobo *et al.,* 2002).

Tree biomass (above and below ground) and biomass carbon are other most important parameters. Growing woody perennials under Agroforestry systems can be considered to be the most effective alternatives which can mitigate climate change. It is having a high potential for sequestering carbon under the climate change mitigation strategies (Watson *et al.*, 2000). It was reported that Agroforestry can sequester an average of 25 Mg C ha^{-1} (Sathaye and Ravindranath, 1998), but there are variations in carbon sequestration potentials and thereby have differences in biomass production in different regions of the country (Ramnewaj and Dhyani, 2008 and Dhyani *et al.,* 2009). To quantify the tree biomass and biomass carbon of that AFS, the dynamic carbon accounting model CO2FIX v3.1 was considered for assessing the baseline tree biomass and biomass carbon (Masera *et al.,* 2003; Schelhaas *et al.* 2004; Ajit *et al.,* 2013). CO2FIX has been extensively used for estimating biomass and changes in soil carbon stocks for forestry, agriculture and agroforestry projects since the estimates do consider soil, climate and any other factors like crop residues *etc.*. CO2FIX was preferred over others (viz PROCOMAP, CENTURY and ROTH) for the present study since only CO2FIX can simulate the carbon dynamics of single/multiple species simultaneously, and can handle trees with varied ages and agroforestry systems (Ajit *et al.,* 2013). In order to run this model, Current Annual Increment (CAI) of the species is very important and was estimated by using the volume equations (Ravindranath and Ostwal, 2008), which was obtained by averaging the tree volumes (V_1 & V_2) after considering trees as average of cylindrical and conical shape.

Tree volume, V_1 (m^3 $tree^{-1}$) = (π x DBH^2 x H)/4 (for cylindrical shape).. (1)

Tree volume, V_2 (m^3 $tree^{-1}$) = (π x DBH^2 x H)/12 (for conical shape).. (2)

Thus, V (m^3 $tree^{-1}$) = (V_1 + V_2)/2.. (3)

Where, H = Tree height (in meter)

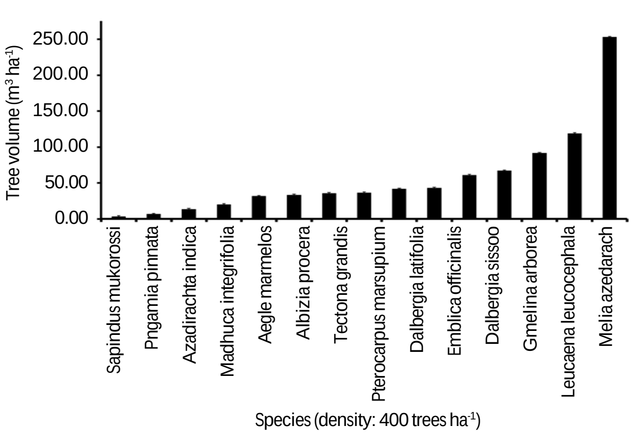

Figure 1: Growth performance of trees (10 year old)

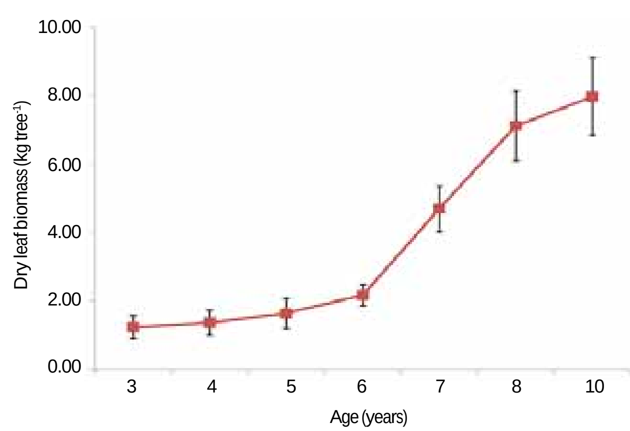

Figure 2: Dry leaf biomass production from trees of different ages

Hence, the CAI thus obtained from the volume equation was tabulated in Table 2.

Comparative studies on soil properties under the trees of bakain of 10 years age with that of fallow land were also undertaken to understand the nutrient dynamics of that agroforestry system.

Farmer's field

From farmer's fields in four villages of Ranchi district of Jharkhand (Hundru, Chhotaghagra, Plandu and Ormanjhi), a questionnaire based survey were also carried out (a minimum of 30 households from each villages) to assess the profits made from Bakain based AFS and all the related parameters including timber and fuelwood selling price and crosschecked from nearby/ local markets. The value of the timber thus they sell was estimated in terms of Indian Rupees at the prevailing market rate.

Dry leaf biomass production from trees of different ages (3, 4, 5, 6, 7, 8 and 10 years old) and dry branch biomass from the same trees as annual fuelwood source were also estimated from the study areas following destructive methods.

A method of ranking of tree species, on the basis of farmers' preference taking a set of all possible uses into consideration, has been developed heuristically. It is the most advanced and modified form of ranking developed for the first time than the method explained earlier by Khan and Tewari (2009) for ranking the fuelwood species. During the survey, the villagers were asked to rank the species they prefer based on criteria given in Table 7. And matrix ranking of 5 selected forest tree species has been done using this method. The species were ranked from 1 to 5 (1 for species of high preference and 5 denotes species of low preference). Finally, data were analyzed and the weighted score of the species were generated for future need to understand the actual demands and usefulness.

$$Ws = \sum XiYi \quad \text{......} \quad \textbf{(4)}$$

Where, W_s = Weighted score of particular species (Lowest score indicates high preference and *vice-versa*)

X_i = Importance value of i^{th} parameter

Y_i = Ranking of i^{th} parameter

Statistical analysis

Systat-12 software (Wilkinson and Coward, 2007) was used for computation of descriptive statistics (mean, standard deviation, *etc.*) in all the estimates and level of significance were determined for comparative studies of soil properties under bakain based AFS (10 years old) vs fallow as control.

RESULTS AND DISCUSSION

When compared with different multipurpose trees of same age (10 years old), the tree volume of bakain (*M. azedarach*) was found the highest (252.88 m^3 ha^{-1}) followed by *Leucaena leucocephala* (118.89 m^3 ha^{-1}) and *Gmelina arborea* (91.47

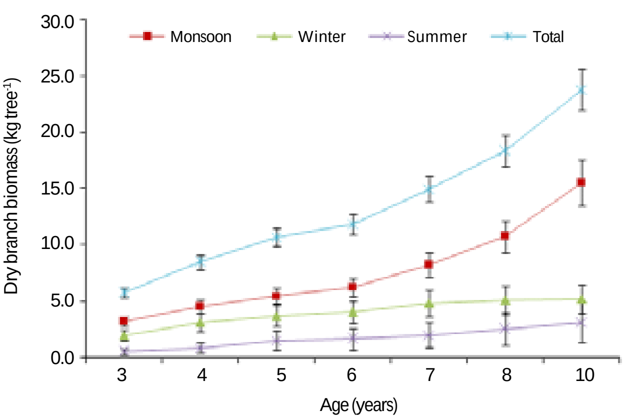

Figure 3: Yearly and seasonal pattern of extraction of dry branch biomass as fuelwood from bakain tree

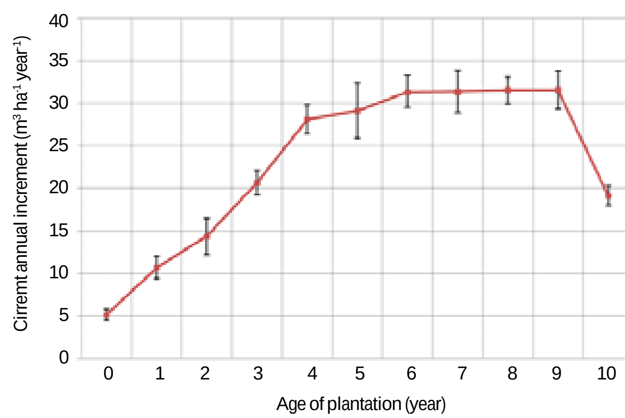

Figure 4: Annual increment of trunk volume at different ages of the tree

Table 1: Morphometric characteristics of the study area (Research farm of ICAR RCER, Research Centre, Plandu, Ranchi, Jharkhand)

Sl. No.	Attributes	Details	
1.	Locations	Latitude	23° 16' 19.73" N
1.		Longitude	85° 20' 49.99" E
2.	Altitude (m)	657.76	
3.	Rainfall (mm)	846.02	
4.	Soil type	Alfisol	
5.	Region	Eastern Plateau and Hill Region	
6.	Multipurpose Trees (MPTs) based Agroforestry systems	*Aegle marmelos* (L.) Corrêa., *Albizia procera* (Roxb.) Benth, *Azadirachta indica* A. Juss., *Dalbergia latifolia* Roxb., *Dalbergia sissoo* Roxb., *Emblica officinalis* Gaertn., *Gmelina arborea* Roxb., *Leucaena leucocephala* (Lam.) de Wit., *Madhuca integrifolia* J. F., *Melia azedarach* L., *Pongamia pinnata* (L.) Pierrre, *Pterocarpus marsupium* Roxb., *Sapindus mukorossi* Gaertn., *Tectona grandis* Linn. and *Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	

m^3 ha^{-1}) and the lowest was observed in case of *Sapindus mukorossi* (3.45 m^3 ha^{-1}) (Fig. 1). That bakain is a very fast growing species, is evident from the high values of diameter at breast height (29.90 ± 2.24 cm), tree height (9.0 ± 2.71 m) and tree volume (0.63 ± 0.09 m^3 $tree^{-1}$) after 10 years of planting (Table 3). The canopy spread area (40.36 ± 4.55 m^2) indicated its suitability to be planted at higher densities. The timber is mainly utilized for making poles and low value furniture.

Besides all the direct socio-economic benefits of this species, it also improves the environmental health on account of its high carbon sequestration potential. The estimated annual carbon sequestration by tree biomass (above and below ground) of ten years old *M. azedarach* based AFS was found to be 10.72 ± 2.11 Mg C ha^{-1} (Table 3). It was understood that, site specific climatic parameters like monthly temperature, annual precipitation and evapotranspiration play important role in moderating the tree biomass and biomass carbon accumulation (above and below ground) in different AFS (Ajit *et al.*, 2013). The high values of carbon sequestration potential can be attributed to high values of Leaf area (290.21 ± 4.38 cm^2) and Specific Leaf Area (5403.76 ± 184.00 cm^2 g^{-1}) (Table 3) and can also be attributed to having high rate of photosynthesis (ratio 3.18) as compared to other species like in *Tectona grandis* (3.15) and *Bombax ceiba* (3.15) (Kumar and Kumari, 2010). It was stated that as the leaf area increases the plant growth and development also increases (Abajingin and Ajayi, 2015). Specific leaf area was considered as one of the most widely accepted key leaf character for the study of leaf traits (Hoffmann *et al.,* 2005). They generally differed with the variations in the thickness of leaves as reported earlier (Wilson *et al.,* 1999). The foliage of the tree also creates suitable conditions for intercropping of different crops in the system (Leaf Area Index (LAI) was estimated as 8.94 ± 0.08, Photosynthetically Active Radiation under canopy as 237.78 ± 0.08 µ mol m^{-2} s^{-1}, PAR absorbed/ reflected as 1535.37 ± 0.15 µ mol m^{-2} s^{-1}, PAR under canopy as 13.41 ± 0.97 % and PAR absorbed/ reflected as 86.59 ± 3.25 %. As such, LAI plays an essential role in theoretical production ecology (Breda, 2003). Waring *et al.* (1982) has suggested that within a single tree, more exposed foliage absorbs more radiation and has higher photosynthetic rates than shaded foliage. This plant is largely utilized by the tribal farmers for fodder purpose, particularly for small ruminants like sheep and goats. The quantity of dry leaves as fodder from 10 years old bakain tree was estimated as 3.19 ± 0.90 t ha^{-1} and found to have dry matter content (20.00 ± 2.99 % of fresh leaf biomass) and crude protein ranging from 12.10 ± 2.21 % (Table 4).

Studies on changes in soil properties under this system indicated significant increase in the soil pH and electrical conductivity under the ten years old tree, whereas, there was a significant decrease in the available nitrogen and potassium at the depth of 0-15 cm (Table 5). Hence this system can be useful for reclamation of acid soils biologically and provide greater scope for raising fruits and vegetables of farmer's interest. Trees generally enrich the soil below them in terms of nutrient contents like Ca, Mg, K, Na, P and N (Szott et *al.,* 1991), the threshold level, upto certain age of the plantations or the system, some of the nutrients may get oxidized or reduced in some form and moved out of the system. Moreover, the positive changes in the soil pH, electrical conductivity and even soil organic carbon at different depths of soil under the tree canopy can be attributed to positive impact of the management practices on soil organic matter content and on the soil quality (Padbhushan *et al.,* 2015). This study also indicated the need for replenishment of nutrient in the upper surface of the soil for maintaining the soil fertility in 10 or more than 10 years old bakain based agroforestry system on long term basis. Similar recommendation was also made for a 10 years old mango based agri-horticultural system (Das *et al.,* 2017).

Table 2: Estimated Current annual increment (CAI) of the stem volume growth (m^3 ha^{-1} $year^{-1}$) over years for bakain tree

Sl. No.	Bakain Age	CAI
1.	0	5.14 ± 0.62
2.	1	10.67 ± 1.28
3.	2	14.32 ± 2.15
4.	3	20.66 ± 1.45
5.	4	28.10 ± 1.69
6.	5	29.11 ± 3.30
7.	6	31.33 ± 1.88
8.	7	31.35 ± 2.51
9.	8	31.54 ± 1.58
10.	9	31.54 ± 2.21
11.	10	19.12 ± 1.15

Table 3: Growth attributes of *M. azedarach* (10 years old)

Attributes	*M. azedarach*
Diameter at breast height (cm)	29.90 ± 2.24
Tree height (m)	9.00 ± 2.71
Tree volume (m^3 $tree^{-1}$)	0.63 ± 0.09
Canopy spread area (m^2)	40.36 ± 4.55
Leaf area (cm^2)	290.21 ± 4.38
Specific Leaf Area (cm^2 g^{-1})	5403.76 ± 184.00
Leaf Area Index	8.94 ± 0.08
Photosynthetically Active Radiation (PAR) under canopy (µ mol m^{-2} s^{-1})	237.78 ± 0.08
PAR absorbed/ reflected (µ mol m^{-2} s^{-1})	1535.37 ± 0.15
PAR under canopy (%)	13.41 ± 0.97
PAR absorbed/ reflected (%)	86.59 ± 3.25
Estimated annual carbon sequestration by tree biomass (above and below ground) (Mg C ha^{-1} yr^{-1}) for 400 trees	10.72 ± 2.11
Estimated annual carbon sequestration by tree biomass (above and below ground) (Mg C $tree^{-1}$ yr^{-1})	0.03 ± 0.01
Income from trees per hectare @ ¹ . 800 $tree^{-1}$ for 400 trees (Rupees)	320000

Table 4: Fodder quantity and quality extracted from bakain trees (10 years old)

Parameters	Values
Dry leaves (t ha^{-1}) from 400 trees	3.19 ± 0.90
Dry leaf biomass (kg tree^{-1})	7.98 ± 2.25
Dry matter content in leaves (%)	20.00 ± 2.99
Crude protein content (%)	12.10 ± 2.21

trees attained 10 years old age (7.98 kg tree^{-1}) (Fig. 2). Where in the case of total dry branch biomass productions (kg tree^{-1}) over the years when estimated were found highest (23.81 kg tree^{-1}) in case of trees attained an age of 10 years (Fig. 3). The annual increment of trunk volume found to reach a plateau phase at 9 years of age. Therefore, 9th year is the most appropriate stage to harvest the tree from economical point of view (Table 2 and Fig. 4). Upto an age of 3 years, trees were too small to exhibit any dry branch biomass. But from the trees of 3 years onwards, minimal harvests could be obtained and were recorded as 5.71 kg tree^{-1} and the increasing trend was observed for the increased tree age (Fig. 3). When compared the different seasons of harvests, the highest quantity of dry branch biomass as used as fuelwood was recorded during monsoon followed by winter and the least was recorded during summer (Fig. 3).

Table 5: Comparison of soil properties under bakain based AFS (10 years old) vs fallow as control

Parameters	Soil depth (cm)	Treatments *M. azedarach*	Fallow as control	Significant difference from control ($p < 0.05$)
pH	0-15	5.84 ± 0.56	5.32 ± 0.12	*
	15-30	6.15 ± 0.43	5.30 ± 0.01	**
EC (µM/cm^{-1})	0-15	0.07 ± 0.02	0.03 ± 0.00	*
	15-30	0.09 ± 0.04	0.02 ± 0.00	**
Soil organic carbon (%)	0-15	0.55 ± 0.11	0.64 ± 0.18	NS
	15-30	0.61 ± 0.05	0.49 ± 0.06	*
Available nitrogen (Kg ha^{-1})	0-15	293.00 ± 33.20	388.20 ± 29.30	*
	15-30	393.80 ± 19.70	375.20 ± 19.40	NS
Available phosphorus (Kg ha^{-1})	0-15	3.29 ± 0.58	3.36 ± 1.94	NS
	15-30	9.34 ± 2.07	13.45 ± 4.92	NS
Available potassium (Kg ha^{-1})	0-15	177.60 ± 45.60	276.80 ± 15.20	**
	15-30	305.60 ± 79.60	276.00 ± 29.10	NS

* Level of significance at $p < 0.05$

Table 6: Income from different plant products over the years

Age of plant (year)	Income from different plant products (in Rs.Tree^{-1})	
	Timber	Dry branchwood
5	0.00 (0.00)	36.69 (0.54)
6	600.00 (8.81)	40.59 (0.60)
7	800 (11.75)	51.43 (0.76)
8	850 (12.48)	62.91 (0.92)
10	850 (12.48)	81.63 (1.20)

Table 7: Matrix ranking for preferred species by 30 farmers from each village

Species	Ranking of the species from 1 to 5 (1 for high preference and 5 for low preference				
Parameters	*Gmelina arborea*	*Tectona grandis*	*Melia azedarach*	*Dalbergia sissoo*	*Bombax ceiba*
Preciousness of timber[4]	3	1	5	2	4
Use as timber[3]	2	1	5	3	4
Use as fodder[6]	3	5	1	2	4
Use as fuelwood[5]	3	4	1	2	5
Medicinal use[7]	3	4	1	2	5
Other uses (Non Timber Forest Products)[8]	5	4	1	2	3
Crop cycle[2]	2	3	1	4	5
Monetary benefit[1]	2	1	4	3	5
Weighted score	118	124	67*	80	151

Lowest score indicate high preference and *vice-versa.* Superscripts (1 to 8) indicate importance of the parameters (1 for highly important and 8 for less important) and were used for calculation of weighted score.

Survey at farmer's fields indicated that farmers earn ¹ .Rs. 600 - 800 per tree by selling 6-10 years old trees to local furniture makers (Table 3 & 6). Now-a-days, farmers of the region are raising this species only on the farm boundaries as a shelterbelt or wind breaks. Values in the bracket are in Dollar ($): 1 $ = Rs . 68.10 (Rate as per dated 23/01/2017). It was estimated that, the dry leaf biomass production (kg tree^{-1}) was less (ranged from 1.23 to 2.16 kg tree^{-1}) upto an age of 5 – 6 years but from the 7th year onwards there was a accelerated increase in the fodder production and the highest was observed in case of

Most preferred tree species in the Jharkhand that are generally grown by the farmers were ranked by the villagers (in study areas) based on different criteria like preciousness of timber, use as timber, use as fodder, use as fuelwood, medicinal use, other uses (Non Timber Forest Products), crop cycle and monetary benefit. The overall grading after assigning ranks by the villagers on a scale of 1-5 (1 for high preference and 5 for low preference) were analyzed, compiled and tabulated (Table 7). From the result, it was evident that *M. azedarach* got the first rank (Weighted score (67) by the villagers followed by *D. sissoo* (weighted score 80) and so on. Whereas the least score was given to *B. ceiba* (weighted score 151) (Table 7). Based on all the criteria, *M. azedarach* was found to be the species most preferred by the villagers.

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