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An evaluation of fuelwood properties of some Aravally mountain tree and shrub species of Western India

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ABSTRACT

The study analyses the fuelwood characteristics of 26 trees including shrub species from the dry deciduous forest in Aravally region, Rajasthan, Western India was carried out to explore trees with potential for fuelwood production. Fuelwood value index (FVI) based on the properties of calorific value, wood density and ash. Calorific value was ranged between 18.54 ± 0.04 and 27.44 ± 0.09 KJ g^{-1} in *Jatropha curcus* and *Wrightia tinctoria* respectively. Wood density varied from 0.538 ± 0.01 to 0.966 ± 0.07 g/cm^3 in *J. curcus* and *Acacia nilotica*. Same way ash and moisture content was highest in *J. curcus* ($3.38 \pm 0.19\%$) and *Sterculia urens* ($70.28 \pm 7.52\%$) and lowest in *Miliusa tomentosa* ($0.85 \pm 0.06\%$) and *Azadirachta indica* ($30.7 \pm 10.02\%$) respectively. On the basis, of the 26 species analyzed, *M. tomentosa* has the highest FVI, followed by *Lannea coromandelica*, *Acacia leucophloea*, *Madhuca indica*, *A. nilotica*, *W. tinctoria*, *Butea monosperma*, *Zizyphus nummularia*, *S. urens*, *Boswellia serrata*, *A. indica*, *Grewia tenax*, *Syzygium cuminii*, *Tectona grandis* and *Dalbergia sissoo* were shown to have promising fuelwood production.

1. Introduction

In the third-world countries, the majority of the population lives in the rural areas where fuelwood, charcoal, crop residues and animal wastes provide most of the energy requirement. In Indian mountain villages fuelwood is the only main source of energy, supplying almost all of the cooking energy requirement [1]. In India, about 70% of energy requirement is by the fuelwood, collected from the forests and nearby sites and about 50 million tons of wood are removed every year. The Aravally hill region is not exception, where people have dependent heavily upon plant resources for meeting their energy needs in addition to various other requirement like Major and Minor Forest Produce [2].

In Aravally region, the tribal dependence on forest for fuelwood, as a primary source of energy, coupled with shifting cultivation is causing serious deforestation in this region to a great extent [3], which necessitates the raising of energy plantation in unused lands and wasteland of the region. Commercial fuel is beyond the reach of the tribal communities due to their poor socio-economic conditions [4]. Due to an ever increasing population, fuelwood consumption is increasing rapidly. The average fuelwood consumption is significantly high (5.9–6.4 kg/day/capita) for Aravally region as compared to other parts of India [5,6].

This level of fuelwood consumption has resulted in over exploitation of natural resources; consequently, the region is experiencing scarcity of fuelwood. To overcome the problems,

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various governmental as well as non-governmental agencies are engaged in developing energy plantations in the region [7]. Foundation for ecological security (FES) is engaged in reforestation of suitable degraded lands with improved forest management practices can provide a wide range of environmental, social and economical benefits and open up various scientific and entrepreneurial opportunities which will yield numerous advantages in the long run in this region. However, scanty literature is available on fuelwood properties in India, therefore, the present study was undertaken to evaluate fuelwood properties of some Aravally mountain tree and shrub species of Western India.

2. Materials and methods

2.1. Samples

Randomly selected branch cuttings (2–3 cm diameter) of *W. tinctoria* (Roxb.) R. Br.; *Madhuca indica* J.f. Gmelin; *Prosopis cineraria* (L.) Druce; *Acacia nilotica* Willd.; *Syzygium cuminii* (L.) Skeels; *Zizyphus nummularia* (Burm.f.) W. & A.; *Butea monosperma* (Lam.) Taub.; *Miliusa tomentosa* (Roxb.) Sinclair; *Acacia leucophloea* (Roxb.) Willd.; *Azadirachta indica* Juss.; *Bombax ceiba* L.; *Sterculia urens* Roxb.; *Lagerstroemia* Pers.; *Boswellia serrata* Roxb.; *Dalbergia sissoo* Roxb.; *Lannea coromandelica* (Houtt.) Merr.; *Tectona grandis* L.; *Cordia gharaf* (Forsk.) Ehrenb. & Asch; *Cassia fistula* L.; *Albizia lebbek* (L.) Benth.; *Capparis decidua* (Linn..) Pax.; *Rhus mysurensis* (Linn.) Heyne; *Grewia tenax* (Linn) Fiori; *Lantana camara* L. and *Jatropha curcas* L. were collected from the dry tropical region of Aravally hills Rajasthan during January, 2009. These were divided four replicates of 10 cm length. Samples were oven dried at 80 °C and made powder.

2.2. Moisture content

Moisture content of wood was determined after drying it at 100 ± 5 °C for 48 h [11].

$$\text{Moisture content} = \text{Fresh weight} - \text{Dry weight}$$

2.3. Wood density

The wood density was determined with the Smith method [9], which avoids the need to determine the exact volume of the samples. The samples were subjected to cycles of over- and under-pressure in a water tank for 5 days. Subsequently the saturated weight was determined and after 24 h of drying the oven-dry weight. The wood density can be calculated according to

$$\text{Wood density}(\text{g/cm}^3) = (1/[(m_{\text{saturated}} - m_{\text{oven dry}})/m_{\text{oven dry}}] + 1/1.53)$$

2.4. Calorific value

The calorific value of dried powdered of wood samples was determined with a Rajdhani® bomb calorimeter, in which about 0.5 g of oven dried wood was completely combusted under a pressurized to 425 psi with pure oxygen, and the rise in temperature of the cylinder allows the calculation of the calorific value when the exact weight of the sample is known. The bomb calorimeter was calibrated against benzoic acid standards before the analysis of samples [8].

2.5. Ash content

The ash content was determined according to TAPPI standard T 211 om-85 [10]. Wood samples were weighed before they were placed in a furnace at 575 °C for 4 h. Subsequently the ash was weighed and the ash content determined according to

$$\text{Ash content} = m_{\text{ash}} \times 100/m_{\text{oven dry}}$$

2.6. Fuelwood value index (FVI)

Fuelwood value index based on the properties of calorific value, wood density and ash [12].

$$\text{Fuelwood Value Index (FVI)} = \text{Calorific Value(KJ/g)} \times \text{Wood density}(\text{g/cm}^3) / \text{Ash content}(\%)$$

3. Result and discussion

Calorific value was ranged between 18.54 ± 0.04 and 27.44 ± 0.09 KJ g^{-1} in *Jatropha curcus* and *W. tinctoria* respectively. Wood density varied from 0.538 ± 0.01 to 0.966 ± 0.07 g/cm^3 in *J. curcus* and *A. nilotica*. Same way ash and moisture content was highest in *J. curcus* (3.38 ± 0.19%) and *S. urens* (70.28 ± 7.52%) and lowest in *M. tomentosa* (0.85 ± 0.06%) and *A. indica* (30.7 ± 10.02%) respectively. Overall the biomass/ash content ratio was the highest for the *M. indica* (72.7), followed by *M. tomentosa* (69.3), *A. indica* (57.1), *A. leucophloea* (50.3) and *A. nilotica* (46.7) and the value was lowest in *J. curcus* (13.3) (Table 1). The quality of fuelwood depends on quantitative and qualitative properties of wood. Quantitative properties include calorific value, wood density, moisture content, ash content, drying rate, chemical composition. Although most of the earlier work emphasized the dried wood calorific value more than gross calorific value of non-dried wood, it is not as important as there is no significant difference between the majorities of the species. Further, effective calorific value also depends on the moisture content. The higher the moisture content, the less efficient is the wood as a fuel since the net calorific value for heating is reduced [13]. Moreover, it has been recorded that the moisture content varies with the dimensions of branches, season of the year and so on. Thus, water content cannot be considered as part of the intrinsic value of a species as a fuel. Therefore, for the estimation of ideal fuelwood species, a fuelwood value Index was calculated as calorific value × density/ash.

Keeping this in view, a combination of four factors: Calorific value, wood density and ash are most appropriate in determining the suitability of a wood as fuel. On the basis, of the 26 species analyzed, *M. tomentosa* has the highest FVI, followed by *M. indica, A. leucophloea, A. nilotica, A. indica, W. tinctoria* and *L. coromandelica*. Fuelwood properties of various trees and shrubs species of Aravally region are shown in Table 1. The calorific values are higher than the range reported by

Table 1 – Calorific value and other firewood characteristics of some mountain tree and shrub species of Aravally mountain region.

Plant species	Calorific value KJ/g dry weight	Wood density g/m^3	Ash (%)	Biomass/ash ratio	Moisture (%)	Fuelwood value index (FVI)
Wrightia tinctoria (Roxb.) R. Br.	27.44 ± 0.09	0.935 ± 0.03	1.39 ± 0.17	43.77 ± 5.20	39.31 ± 11.69	1849.63 ± 19.60
Madhuca indica J.f. Gmelin.	27.04 ± 0.03	0.952 ± 0.01	0.94 ± 0.08	72.70 ± 6.37	31.90 ± 14.62	2747.91 ± 56.23
Prosopis cineraria (L.) Druce	26.63 ± 0.06	0.867 ± 0.00	2.68 ± 0.17	24.05 ± 8.28	35.55 ± 7.50	861.90 ± 30.12
Acacia nilotica Willd.	26.63 ± 0.10	0.966 ± 0.07	1.31 ± 0.12	46.72 ± 10.50	38.80 ± 9.20	1963.18 ± 64.12
Syzygium cuminii (L.) Skeels	26.23 ± 0.04	0.893 ± 0.03	2.16 ± 0.14	28.15 ± 12.21	39.20 ± 4.69	1084.72 ± 27.14
Zizyphus nummularia (Burm.f.) W. & A.	26.23 ± 0.07	0.908 ± 0.00	1.48 ± 0.19	39.05 ± 16.70	42.20 ± 12.60	1609.09 ± 34.12
Butea monosperma (Lam.) Taub.	25.82 ± 0.11	0.883 ± 0.02	1.87 ± 0.23	23.57 ± 13.20	56.01 ± 5.30	1221.52 ± 31.14
Miliusa tomentosa (Roxb.) Sinclair	25.82 ± 0.05	0.927 ± 0.06	0.85 ± 0.06	69.32 ± 21.00	40.85 ± 12.48	2804.22 ± 67.20
Acacia leucophloea (Roxb.) Willd.	25.82 ± 0.08	0.932 ± 0.01	1.05 ± 0.10	50.28 ± 10.00	47.21 ± 8.32	2292.1 ± 72.23
Azadirachta indica Juss.	25.82 ± 0.03	0.911 ± 0.04	1.21 ± 0.13	57.12 ± 15.23	30.70 ± 10.02	1939.56 ± 44.20
Bombax ceiba L.	25.42 ± 0.12	0.882 ± 0.00	2.45 ± 0.15	23.78 ± 9.24	41.65 ± 8.64	913.82 ± 21.12
Sterculia urens Roxb.	25.42 ± 0.09	0.700 ± 0.00	1.86 ± 0.18	16.00 ± 8.39	70.28 ± 7.52	958.33 ± 29.60
Lagerstroemia speciosa Pers.	25.42 ± 0.14	0.872 ± 0.07	2.43 ± 0.21	27.85 ± 6.28	32.23 ± 12.06	910.54 ± 31.23
Boswellia serrata Roxb.	25.01 ± 0.10	0.891 ± 0.08	1.69 ± 0.13	30.07 ± 10.21	49.28 ± 8.78	1321.89 ± 54.92
Dalbergia sissoo Roxb.	25.01 ± 0.09	0.931 ± 0.04	1.94 ± 0.25	35.01 ± 12.32	32.20 ± 11.79	1202.91 ± 26.72
Lannea coromandelica (Houtt.) Merr.	25.01 ± 0.13	0.919 ± 0.05	1.27 ± 0.20	31.10 ± 7.48	60.50 ± 12.46	1810.73 ± 57.23
Tectona grandis L.	24.61 ± 0.07	0.923 ± 0.00	1.93 ± 0.18	33.66 ± 9.23	34.92 ± 10.10	1174.89 ± 23.89
Cordia gharaf (Forsk.) Ehrenb. & Asch.	24.21 ± 0.11	0.874 ± 0.04	2.14 ± 0.24	30.07 ± 16.50	35.55 ± 8.79	987.40 ± 15.12
Cassia fistula L.	23.40 ± 0.06	0.882 ± 0.01	2.56 ± 0.28	21.63 ± 3.39	44.55 ± 16.52	804.72 ± 20.12
Albizia lebbek (L.) Benth.	22.99 ± 0.17	0.864 ± 0.02	3.09 ± 0.31	19.79 ± 8.39	38.85 ± 10.32	642.62 ± 23.10
Capparis decidua (Linn.) Pax.	22.59 ± 0.02	0.684 ± 0.00	3.31 ± 0.23	16.85 ± 6.42	44.10 ± 7.50	465.82 ± 39.12
Rhus mysurensis (Linn.) Heyne	20.56 ± 0.08	0.749 ± 0.02	1.96 ± 0.17	32.66 ± 12.57	36.10 ± 11.32	786.85 ± 30.12
Grewia tenax (Linn.) Fiori	20.16 ± 0.05	0.726 ± 0.00	1.71 ± 0.11	28.89 ± 9.23	50.50 ± 8.52	854.26 ± 21.23
Lantana camara L.	19.35 ± 0.11	0.697 ± 0.09	2.15 ± 0.26	27.69 ± 8.50	40.55 ± 7.23	628.61 ± 26.12
Jatropha curcas L.	18.54 ± 0.04	0.538 ± 0.01	3.38 ± 0.19	13.30 ± 3.39	55.10 ± 12.00	295.61 ± 19.12

earlier workers, North East India [14]. *W. tinctoria* revealed the highest calorific value, followed by, *P. cineraria*, *A. nilotica* and *S. cuminii* respectively. An ideal fuelwood species should have high calorific, high wood density and low ash content. In the present survey, only tropical and sub-tropical tree species were screened. Earlier researchers have reported that tropical species had comparatively higher ash and water content than temperate species. The present findings are in agreement with those reported by earlier workers [15]. Species like *M. tomentosa*, *M. indica*, *A. leucophloea*, *A. indica* and *A. nilotica* can also be considered good fuelwood species on account comparatively low ash content. Whereas tree species like *A. lebbek, L. speciosa, P. cineraria, C. gharaf* and *C. fistula* can be recommended for fuelwood farming as these species exhibit high ash content and low wood density wood.

Aravally region is rich in flora and fauna, however, due to shifting cultivation and large scale deforestation by tribal communities, the region is experiencing serious ecological threats. The fuelwood consumption is very high in Aravally region (5.9–6.4 kg/capita/day) [16] as compared to the value reported for rural communities in the western Himalayas (1.49 kg/capita/day) by Bhatt [5], for southern India (1.9–2.2 kg/capita/day) by Reddy [17] and Hedge [18], and for South and South East Asian countries (1.7–2.5 kg/capita/day) by Donovan [19] and Wijesinghe [6]. This high fuelwood consumption has brought about 50% areas of most of the states of Aravally region, e.g., Gujarat, Rajasthan, Uttar Pradesh and Delhi under wasteland.

The region has a characteristic feature in that almost the entire population belongs to different tribal communities like Garasiya and Gameti, which differ in their social-cultural structure and socio-economic status. Animal husbandry is closely linked to shifting cultivation in the region. Poultry, cattle, rabbit, goat and sheep are some of the important livestock, which are reared for manure, milk, meat, and beef purposes. Therefore, cooking consumes most of the energy because food is cooked for livestock too. It is also one of the reasons why the fuelwood consumption is very high [20].

From the present study, we recommended that *A. nilotica, T. grandis, B. monosperma, P. cineraria* and *Albizia lebbek* be considered for energy plantation programme in Aravally region, India. However, it is necessary to determine the growth rates and productivity of these tree species under different ecological conditions, their optimum planting wood density and rotation period before including them under energy plantation programme.

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