Biomass and Coppicing Ability of Genetically Improved
*Calliandra calothyrsus* for Wood-Energy with Different Spacing

R L Hendrati, N Hidayati and SH Nurrohmah

Center for Forest Biotechnology and Tree Improvement, Ministry of Environment and Forestry, Jl. Palagan Tentara Pelajar km 15, Purwobinangun, Pakem, Yogyakarta 55582, Indonesia

email: rina.l.hendrati@biotifor.or.id

Abstract. Beside wood quality, biomass and ability to coppice of fast-growing woody species for renewable energy are two essential indicators. Appropriate spacing among individual plant is therefore required to get the best harvest. This study is observing biomass, branching and coppicing ability of *Calliandra calothyrsus* at different spacings. Initial experimental plots were using 5 blocks of 16 individuals at spacings of 0.5x1; 1x1; 0.5x2; 1x2 and 2x2m and assessed at 6 months old around reproductive stage. Due to no significant differences, two spacing plots of 2x1 and 1x1m are compared for biomass and wood dimension assessment from 14 individuals per block replicated into 4 blocks after 3 years. Coppicing ability was counted after 2 months of felling. The results indicated that diameter has positive correlation with number of initial branches as well as number of coppices. Specific gravity of wood is also increasing with diameter. Between the two types of spacing, the first wood production is better for 1x1m than 1x2m with 76.3 ton/ha (152 m3/ha) for 1x1m and 72 ton/ha (144 m3/ha) for 1x2m. This indicates a better production than the predicted MAI from the breeding. Specific gravity is recorded to be better at more spacious distance.

1. Introduction
Renewable energy (RE) has only been prevalent since 1981 introduced in United Nations Nairobi Conference on New and Renewable Sources of Energy [1]. Many developed countries including Sweden, Finland, Austria, Denmark, European Union and the United State of America encourage the use of biomass energy, and this includes the use of wood due to several reasons; environmental, socio-economic, minimizing CO2 emissions and reducing people reliance on oil [1]. Wood or woody materials are lower in ash and nitrogen content than other type of biomass [1]. In processing the wood for any type of renewable energy, the process will include either physical, chemical or biological processes, in which for biological process, biomethanization and alcoholic fermentation of biodegradable organic matter to produce biogas, are usually considered [2]. These processes do not require certain wood types and size, and small branches of fast growing species planted at close spacing would be acceptable [3]. *Calliandra calothyrsus*, a species introduced to Indonesia in around 1936 from Mexico and central America [4], has been very adaptive, well known for fodder, green
manure and bee foraging for its flowers [5] and being recognized as a multipurpose fast growing legume species that fix Nitrogen [6]. Rural people in many countries have been using it as favourable fuel wood and recently often being processed into briquette, pellet, or charcoal [7]. In general, properties of legume tree to produce excellent energy include: (1) vigorous growth especially at early phase; (2) tremendous coppicing; (3) relatively high wood density; (4) high production of dry matter; (5) fast drying and suitable wood combustibility and, (6) relatively easy in harvesting and processing [8], and these properties are possessed by calliandra. High coppicing ability in trees is able to provide yearly harvest from the same main tree which is together with biomass and wood quality are genetically controlled [9-11]. Nowadays, more and more agricultural area is being used for food crops, but some could be used for energy plantations. However, to maximise the yield, beside the use of genetically improved genotypes, appropriate spacing per area need to be considered. In this paper the effect of spacing on the growth and biomass production of genetically improved calliandra is discussed.

2. Materials and methods

2.1. Materials
To establish plantation with different spacings, genetic materials (seeds) as bulks were used by firstly soaking the seeds in hot water and let it cool down for overnight before germination.

2.2. Methods

2.2.1. Replications and treatments
Nursery was prepared for raising seedlings by using 10x15cm polybag with media soil:compost = 2:1. After 3.5 months reaching the height up to 30-40 cm, seedlings were planted by 0.5x1; 1x1; 0.5x2; 1x2 and 2x2m spacings. A number of 16 plants with 2 repetitions were grown for each spacing. After 6 months when some plants had been in a reproduction stage, assessment for growth was conducted. In the second experiment, clones produced from air layering were grown with commonly practiced spacings that are 2x1 and 1x1m. A number of 14 individuals per block replicated into 4 blocks were grown up to 3 years for biomass and wood dimension assessments.

2.3. Parameter
Measurements were recorded for height, diameter and number of branches after 6 months in the first experiment. Data recorded for the second experiment were diameter and height. In this experiment, the volumes of wood biomass were recorded by manual weighing of all the woods of each tree after cutting down at the base of the main stem just above the ground. Wood basic density, regardless of wood position, was assessed in the laboratory for diameter classification of small (2.3 - 2.7cm), medium (3.7 - 3.9cm) and big (4.2 - 4.95cm). Sprouting on the base of each tree after being cut were assessed 2 months afterward.

2.4. Data Analysis
Analysis of variance was used for analyzing the data with spacing as treatment, while relationships between characters were analyzed by using correlations.

3. Results and Discussion

3.1. Results

3.1.1. Growth and Volume
Assessments of growth and biomass at 6 months, when some plants had been mature indicated by bearing flowers, demonstrate that there had been no significant differences among spacing (0.5x1; 1x1; 0.5x2; 1x2 and 2x2m) at all parameters which are height, diameter, number of branches and
volume. Therefore, measurement at more aged plants need to be undertaken. In the second experiment, records of two commonly practiced spacings (2x1 and 1x1m), similarly reveal no significant difference at 3 years of age (Table 1) for height, diameter, as well as number of branches. Nevertheless, the average values indicate tendencies of taller (3%) trees and more (10%) branches for those at 1x1m but bigger (10%) diameter at 2x1m. Differences in the size among trees within the block were more obvious at 1x1 m than at 2x1m.

Table 1. Results and probabilities obtained from analysis of variance of *Calliandra calothyrsus* growth characteristics at spacings of 1x1m and 2x1m

| Characteristic       | Spacing (m) | Mean | Pr>F | Significance |
|----------------------|-------------|------|------|--------------|
| Height (m)           | 1x1         | 3.8  | 0.77 | ns           |
|                      | 2x1         | 3.69 |      |              |
| Diameter (cm)        | 1x1         | 4.41 | 0.38 | ns           |
|                      | 2x1         | 4.88 |      |              |
| No. of branches      | 1x1         | 3.93 | 0.23 | ns           |
|                      | 2x1         | 3.56 |      |              |

Assessments of biomass for both spacings by weighing the wood volume have found that when calculated per ha, total volume and total weight for spacing 1x1m (Figure 1) are slightly higher (6 and 5% respectively) than those from the 2x1m.

![Figure 1](image_url) Wood yield of *Calliandra calothyrsus* after 3 years at 2 spacing

3.1.2. Copiccing ability

At 1x1m, the results of sprouting shoots assessed 2 months after felling demonstrate that the number of shoots has very tight relationships with height (0.44***) and diameter (0.53***) of the main trees. However, for the more spacious spacing 2x1m, only diameter that shows very significant relationship (0.5**) with the number of shoot (Figure 2).
A. B. C. D.

Figure 2. Relationships of number of branches against height and diameter of 3-year *Calliandra calothyrsus* at 1x1 m (A and C) and 2x1 m (B and D) spacings

### 3.1.3. Specific gravity

There has been positive correlation between specific gravity and diameter for 3 years old Calliandra (Figure 3 A) regardless of the branch position on the trees. Further, there have been dissimilarity in term of specific gravities between the 2 types of spacing (Figure 3 B) at different diameters demonstrating that, the more spacious spacing (2x1m) posses higher values with 60% higher at smallest diameter range and 30% at the biggest diameter range.
Figure 3. (A). Positive relationship of specific gravity with diameter of 3-year Calliandra calothyrsus and (B). Specific gravities of different diameters at different spacing

3.2. Discussion
Among the 5 kinds of spacing which were assessed up to reproductive stage at 6 months in the first experiment, there had been no evidence of differences in all growth parameters of calliandra. Therefore, the considerations should not be merely focused on growth. In general, after reproduction stage, which can be reached at 6 months - 1 year, calliandra is known to build biomass massively, thus the effect at further age at particular spacing need to be observed. This is especially important on spacing that is commonly applied in the field which are 1x1m and 2x1m which suggested also by [4]. Observation after 3 years carried out at the second experiment of this study also provide no statistical differences on individual growth characteristics of height, diameter and number of branches (Table 1). However, for the total weighed biomass, although it only has little difference, when applied to thousands of hectare, it should provide additional biomass for 1x1m spacing (Figure 1). When considering the number of seedlings to plant, there will be much difference between the two spacings, which is 10,000 for 1x1m and only half of it (5000) for 2x1m. Here, the second spacing seems to be much less costly to invest. However, with calliandra’s ability to be harvested up to 15-20 years [4] by only planting once, the money spent may not give significant economic influence. In addition, higher number of plants per ha may provide more lasting value for soil amelioration with more trees having extra root structure. Tree roots are projected to become soil supplement with organic matter, to feed soil with biomass, lessen nutrient leakage, recycle subsoil nutrients and improve physical properties of
soil [12]. Further, plantation for short rotation crop for energy has been very common to be practiced at 10,000/ha [13-14].

To create an ideal tree, low competitiveness should be created which allowing a dense filling per unit of area and maximizing in fasten and fuller utilisation of accessible resources [15]. Generally in slow growing species, low competitiveness could cause the need to complete early weed control [15], but this may not a major issue in Calliandra as this species cover the ground immediately especially if planted at close distance of only 2x1m. When we take a look at individual tree, trees which have less competition should have more access to nutrient in the soil and more light above the ground, and this may explain how the growth tends to be better for individual trees from the more distant trees [16], which is shown in this study as bigger diameter at more spacious spacing (Table 1). This means that the individual tree within 2x1m might be better in growth especially the diameter. Therefore, the result of higher total yield in 1x1m is more to the number of trees per area rather than the biomass production of each individual tree. At this 1x1m spacing the canopy will close even faster. When fertilizer is applied, the effectiveness of its use will unlikely to occur due to the closed canopy and optimum foliage mass that has been developed [15], therefore at this spacing fertilizer is less important. In 1x1m space, trees seem to be more competing to each other among the neighboring trees, which give more aggressive trees to occupy the resources. This is indicated by wider range of diameter (0.5 - 11.2 cm) demonstrating tougher competition than the spacious one (1 - 9.3 m). Harvesting woody biomass is more to collecting bulk materials rather than considering individual trees, therefore 1x1m is measured to be more appropriate for this purpose, especially because of the needs of less fertilizer, less weeding but providing higher yield.

After felling, the numbers of Calliandra shoots or coppices that come out from the remaining main-tree trunk near the ground (<5cm height) have been proven to be closely related to the growth characters of the main tree, both with diameter (0.53***) and height (0.44***) at spacing 1x1m. If good growth and size, expressed in height and diameter are considered as the expression of vigor in trees [17], this means that the power of producing coppice is affected greatly by tree vigor. Plant vigor is crucial when competition for light, water and air becomes hard [18]. At spacing 2x1m, when the rivalry is less, although the strength of relationship between diameter and ability to coppice is still relatively strong, it has a slight decrease (0.5**) compared to that of 1x1m (0.53***) and even disappears or no relationship when related to tree height. This may mean that tree height has less or no effect on biomass production at more spacious space. It is therefore at closer spacing of 1x1m, coppice is expected to be more stimulated thus providing more option for shoot selection. Further, high number of shoots has negative effect to the wood basic density and its calorific value; thus, it is advisable to undertake thinning and pruning [19]. In monopodial trees, height together with diameter will represent characters for good biomass and vigor, however for multibranches or sympodial tree like calliandra with the wood volume spread into multi branches, base diameter of the main stem seems to be more crucial for coppicing to produce good biomass than tree height. In trees, diameter has been known to have a very strong correlation with biomass [20 - 22].

Unfortunately, due to uneven number of clones in this trial, it is not possible to assess the effect of clones on coppicing ability of this species. However, calliandra’s growth is genetically controlled, especially diameter ($h^2 = 0.34$), height ($h^2 = 0.38$) and volume ($h^2 = 0.5$) [23]). Considering that coppice is affected by height and diameter which are genetically controlled in this species, different clones which represent different genotypes are most likely to vary in producing coppice. Therefore, it is likely that the number of shoots or coppices produced after cutting-down back the stem in calliandra is also likely to be genetically controlled. Genetic control in tree on coppice is also confirmed in Eucalyptus globulus[10].

Specific gravity is a measure of the ratio of a wood's density (oven dry wood) as compared to water. The higher the specific gravity the higher the density of wood will be. In certain species, specific gravity has been acknowledged to have close relationship with carbon content value, which depicting good quality for wood energy. Higher specific gravity up to 30-60% is found on woods from
the more spacious distance, in this trial. Thus, the more distanced space trial (2x1m) proves to produce a better wood quality for energy than those grew on 1x1m spacing. In this study, positive correlation between specific gravity and diameter is found. It is also approved in one of the species studied by [24]. Basic density is confirmed as main wood characteristic for selecting biomass sources, as it is crucial due to its direct relationship with energy production per unit volume [19]. Wood with high specific gravity should be favoured, as the usage of denser woods will results in an increase in charcoal production at particular volume of wood put into the kiln, and charcoal quality is also improved suitable for various purposes, including in the production of steel and iron [25]. Specific gravity is also mentioned as one of the important characteristics influencing combustion fuel properties [26]. This basic density has also been known as characteristic that is genetically controlled in tree [11]which indicates that variation exist within the species. Through this species, breeding selection has been undertaken for bigger diameter, which positively correlated with quality of wood approached, by lignin content and specific gravity [27]. Positive relationship has also been revealed between specific gravity and calorific value of this species [27]. The advantage of keeping specific gravity at spacing 2x1m at the expense of other benefits when applying 1x1m spacing is therefore arguable and it needs meticulous thought. However, when the product is for briquette, pellet biofuel or biogas, in which the process will determine the quality, the spacing of 1x1m is still preferable.

When Calliandra is used as wood energy, most of its biomass will be usable which include its small twigs. While the wood is for energy, the leaves can be reused back into the area as green manure to improve the next yield. For energy purpose, flowers and seeds of Calliandra may not be as much useful due to quick and routine harvesting of the coppice. Therefore, resource as the products of photosyntesis should not be used for producing flowers and seed but used for forming wood biomass instead. Production of flowers, pollen, seed and seed-bearing organs would decrease the amount of biomass that can be converted into desirable products [28 - 30]. Example of Pinus strobus indicates that the loss of 3.7 m3/ha of wood would happen during the good seed production year [15]. Considering that Calliandra can produce flowers at a very early age, even from the new shoots, harvesting the coppice before producing flowers is suggested.

4. Conclusion
Spacing influences biomass at 3 years Calliandra calothyrsus. Biomass calculation per ha shows that total volume and weight for spacing 1x1m are slightly higher (6 and 5% respectively) than those from the 2x1m. At 1x1m, the results of sprouting shoots demonstrate that the number of shoot has very tight relationships with height and diameter of the main trees. Nevertheless, for the more spacious spacing 2x1m, only diameter shows very significant relationship with the number of shoot. Harvesting woody biomass is more to collecting bulk materials rather than considering individual trees, therefore 1x1m is measured to be more appropriate for this purpose.

Acknowledgements
We thank the Centre Forest for Biotechnology and tree Improvement (CFBTI), Forest Research and Development agency (FORDA) for supporting this research

References
[1] Chuah TG, Wan Azlina AG, Robiah Y and Omar R 2006 Biomass as the Renewable EnergySources in Malaysia: An overview International Journal of Green Energy3(3) 323-346 DOI: 10.1080/01971520600704779
[2] Sawayama, S 1999 Nippon Enerugi Gakkaishi78(4) 259–264
[3] Fulvio DF, Kroon A, Bergstrom D and Nordfjell T 2011 Scandinavian Journal of Forest Research26339-349
[4] Chamberlain JR 2001. Calliandra calothyrsus, An agroforestry tree for the humid tropics, (United Kingdom: University of Oxford)
[5] Robert Kajobe 2007 Springer Verlag38 (1) 110-121
[6] Silva VC, Casaes PA, Rhem MFK, Dos Santos JMF, James EK & Gross E 2018 *Systematic and Applied Microbiology* **41**(3)

[7] Hartono R, Iswanto AH, Hartini KS, Susilowati, A, Elfiati, D, Muhi, Zahra, M, Latifah, S, Batubara, R, Anna, N, Sucipto, T & Azhar, S. 2014 ‘The Utilization of Biomass from Forest and Plantation for Environment Conservation Efforts’. Proceeding The 6th International symposium of indonesian wood research society’, 12-13 November 2014. Garuda Plaza Hotel, Medan, North Sumatera INDONESIA

[8] Nicolescu, VN, Hernea, C, Bakti, B Keserű, Z, Antal, B., Rédei, K. 2018. *J. For. Res.*

[9] Moosseler A, Major JE, Ostafid 2017 *Canadian Journal of Forest Research* **47**(1) 36-46

[10] Whittock SP, Apilola, LA, Kelly CM and Potts BM 2003 *Australian Journal of Botany* **51** 57–67

[11] Langat DK & Kariuki JG 2004. *Journal of Tropical Forest Science* **16**(2) 179-186

[12] Schroth G. 1995. Agroforestry: Science, Policy and Practice **30** 125-143

[13] Djomo SN, Zenone AAT, De Groote T, Bergante S, Facciotto G, Sixto H, Ciria PC, Weger J & Ceulemans R. 2015 Renewable and Sustainable Energy Reviews **41** 845-854

[14] Dillen SY, Djomo SN, Al Afas N, Vanbeveren S & Ceulemans R 2013 *Biomass & Bioenergy* **56** 157-165

[15] Darrow K.1984 South African Forestry Journal **129**(1) 17-20

[16] Barton CVM & Montagu KD 2006 *Forest Ecology and Management* **221**(1-3) 52-62

[17] Collins, G. 2016. *Seedling Vigor: Why Is It Important?*. (NC State University: Crop & Soil Sciences)

[18] Baset MA and Shamsuddin ZH 2009 *Research Journal of Seed Science* **2** 96-104

[19] Rios Saucedo JC, Pons RR, Cancino JC, Carmona EA, Corral Rivas JJ, Serna RR 2018 *Revista Mexicana de Ciencias Forestales* **9**(47).

[20] Jenkins JC, Chojnacky DC, Heath LS and Birdsey RA 2003 *Comprehensive Database of Diameter-based Biomass Regressions for North American Tree Species*. General Technical Report NE-319. United States Department of Agriculture. Forest Service. North eastern Research Station

[21] Comley BWT & McGuinnes KA 2005 *Australian Journal of Botany* **53**(5).

[22] Sone K, Watanabe N, Takase M, Gyokusen K 2014 *Journal of Rubber Research* **17**(2):115-127

[23] Hendrati, R.L. 2015. Genetic Improvement of *Calliandra calothyrsus* for Qualified Wood Energy. Proceeding The International Conference of Indonesia Forestry Researchers III 3rd INAFOR 2015 Bogor, 21-22 October 2015. pp. 535-543

[24] Navarro, M, Moya, R., Chazdon, R., Ortiz, E & Vilchez, B 2013 *BOSQUE* **34**(1): 33-43.

[25] Pereira,BLC, Oliveira, AC, Carvalho, AMML, Carneiro, ACO, Santos, LC & Vital, BR 2012 *International Journal of Forestry Research* **2012** 523025

[26] Demirbas T & Demirbas C 2009 Energy Sources, Part A: Recovery, Utilization, and Environmental Effects **316** 1464-1472

[27] Nainggolan EM 2016. Thesis. (Yogyakarta: Bachelor Science Program of Faculty of Biology. Gadjah Mada University)

[28] Stanley RG 1965 *Agric. Sci. Review* **111**(1): 1-17

[29] Bramlett DL and Belanger RP 1976 *For. Sci.* **22**(4): 461-467.

[30] Wilcox MD, Faulds, Vincent TG, and Poole BR 1980 *Aust. For. Res.* **10**: 169-1114