DOI: 10.17138/TGFT(7)210-213

ILC2018 Poster and Producer paper*

Genetic improvement of *Leucaena leucocephala* for wood energy

Mejoramiento genético de Leucaena leucocephala *para bioenergía*

RINA LAKSMI HENDRATI AND SITI HUSNA NURROHMAH

Centre for Forest Biotechnology and Tree Improvement Research and Development, Indonesian Ministry of Environment and Forestry, Yogyakarta, Indonesia. menlhk.go.id

Keywords: Bioenergy, biofuels, tree legumes.

Introduction

The world demand for woody biomass for energy generation is increasing rapidly (Rakos 2008; Spelter and Toth 2009; Sikkema et al. 2011). Woody biomass from short-rotation crops can contribute to secure renewable and sustainable energy around the world owing to their potential to produce high biomass in short time periods, especially in tropical countries with plentiful rain (Hendrati 2016). Many fast-growing species have high wood quality for energy and an ability to re-sprout for multiple harvests, which is important for economic success. Multipurpose species provide multiple environmental and rural development benefits (Singh et al. 2010) and with genetic improvement, further improvement in yield and efficiency of production are anticipated. Studies on genetic improvement of *Calliandra calothyrsus* for wood energy indicated high heritability value of wood volume ($h^2 = 0.5$) and an increased yield of 75% for wood volume (Hendrati 2016). This paper describes research on the genetic improvement for wood energy of *Leucaena leucocephala*, which is self-fertile and therefore less variable than *Calliandra calothyrsus*, which is not self-fertile. Nevertheless, as 2 subspecies of *Leucaena leucocephala* (ssp. *glabrata* and *leucocephala*) are present in Indonesia, there is some ability for outcrossing, so genetic gain is achievable.

Materials and Methods

Genetic improvement of *L. leucocephala* ssp. *glabrata* (imported leucaena) was initiated by collecting genetic material from 10 established orchards, including cv. Tarramba, during the period 2015–2016. They were from Subang and Majalengka (West Java), Brebes (Central Java), Sleman, Bantul and Kulon Progo (DIY), Bangkalan Madura (East Java), Bali (Bali Island), Menado (North Sulawesi) and Kupang (East Nusa Tenggara). At most sites, the species was grown by villagers for forage, fuelwood and human consumption (seed). *Leucaena leucocephala* ssp. *glabrata* was preferred over common local leucaena (*L. leucocephala* ssp. *leucocephala*) because it has better growth and is more tolerant of psyllids (*Heteropsylla cubana*) than the more susceptible ssp. *leucocephala*. The range in elevations from which these samples were collected was 0–500 masl and precipitation ranged from 800 to 3,050 mm/yr. Open-pollinated half-sib seeds from 80 trees (considered as families hereafter), selected as the best performers in the orchards, were collected. *Leucaena leucocephala* is considered to be a cross-pollinating species but up to 10% selfing is known to occur. Consequently, the collected seeds were considered F1, although some seed may have resulted from self-pollination. A long-term breeding strategy was planned as shown in Figure 1. Progeny tests were established at 2 locations, Wonogiri and Brebes, Central Java (Table 1). This phase of the program is represented by the box 'Progeny test F1 on 2 sites'. Distance between individual mother trees (families) within each population was 70–100 m to avoid inbreeding. Seedlings in the nursery were measured for both stem diameter and height after 4 months and again 6 months after transplanting into the field. Biomass yield after 6 months in the field was estimated using a biomass index (BI; basal diameter^2 × height; Stewart and Salazar 1992). Data from the nursery and from the field were analyzed by using analysis of variance and Duncan's Multiple Range Test.

Correspondence: R.L. Hendrati, Jl. Palagan T. Pelajar km 15, Purwobinangun, Pakem, Sleman, Yogyakarta 55582, Indonesia.
Email: rina.l.hendrati@biotifor.or.id

*Poster presented at the International Leucaena Conference, 1–3 November 2018, Brisbane, Queensland, Australia.

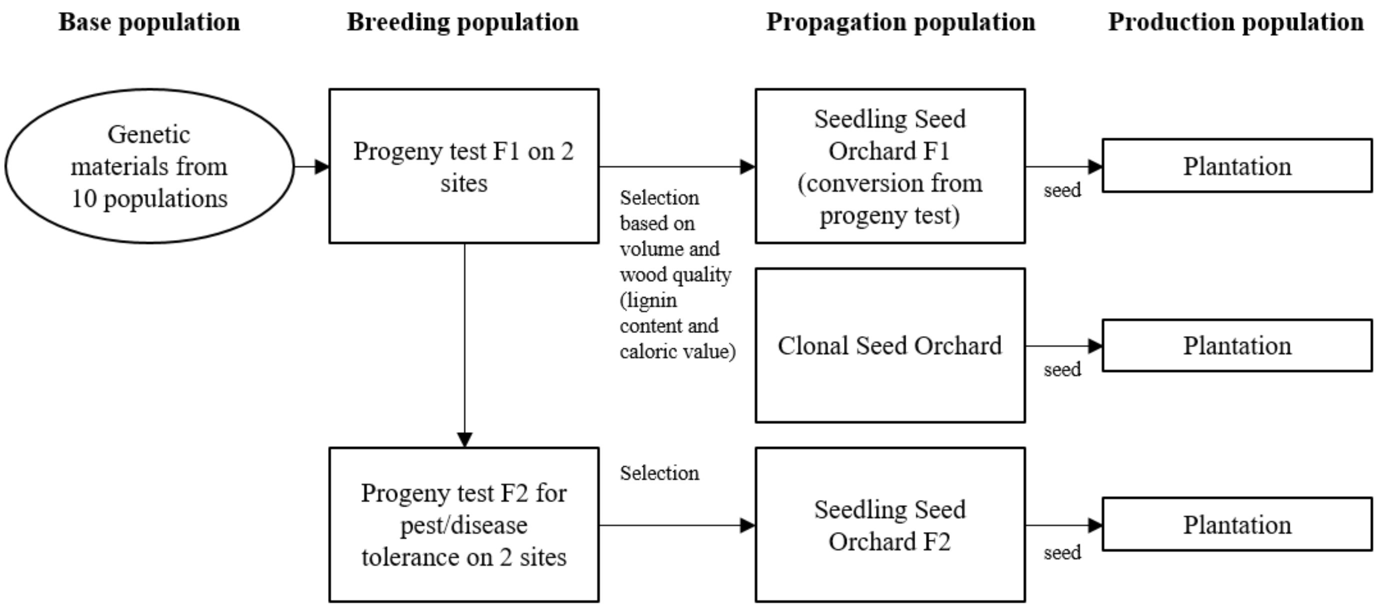

Figure 1. Breeding strategy for *L. leucocephala* to increase wood energy production.

Table 1. Description of *L. leucocephala* ssp. *glabrata* progeny tests established at 2 sites.

No.	Location	No. families	No. populations	Spacing/ block/design	Individuals per family/block	Precipitation (mm/yr), soil type
1	Ketanggungan, Brebes, Central Java	80	10	2 × 2 m/6 blocks/single tree plots	4 (Total = 1,920)	1,961, Vertosol
2	Girimulya, Wonogiri, Central Java	80	10	2 × 2 m/8 blocks/single tree plots	4 (Total = 2,560)	1,800, Alluvial

Early results

After 4 months of growth in the nursery, seedlings were ready for transplanting. At this time, variations in both height and stem diameter were obvious (Table 2). Bantul, Bali, Menado and Kulon Progo populations had diameters comparable with that of cv. Tarramba; for height, only the Bali population was similar to cv. Tarramba. The Subang population always recorded the lowest values for both characters.

Variations between families were re-examined after 6 months in the field (Table 3). While there were significant differences between the 80 families for stem diameter, height and biomass yield (Table 3), results for the best 8 performers for each parameter were not significantly different (P>0.05) (Table 4). Tarramba did not fall within this group for stem diameter but 3 Tarramba families fell in the top 8 families for both height and biomass yield (Table 4).

Table 2. Analysis of growth (diameter and height) of 10 *L. leucocephala* populations from Indonesia after 4 months in the nursery.

Origin	Diameter (cm)	Origin	Height (cm)
Kupang (cv. Tarramba)	0.310a[1]	Kupang (cv. Tarramba)	35.68a
Bantul	0.305a	Bali	35.01a
Bali	0.299ab	Majalengka	32.99b
Menado	0.294ab	Sleman	32.73b
Kulon Progo	0.294ab	Brebes	32.55b
Sleman	0.281bc	Bantul	32.48b
Madura	0.275c	Menado	32.43b
Brebes	0.275c	Madura	31.28b
Majalengka	0.275c	Kulon Progo	31.15b
Subang	0.256d	Subang	27.85c

[1]Means followed by the same letter are not significantly different (P>0.01) by Duncan's Multiple Range test. Source: Hendrati and Hidayati (2018).

Table 3. Results of statistical analysis for growth (diameter, height and biomass) of 80 *L. leucocephala* families after 6 months in the field.

Trait	SV	df	SS	MS	P>F
Diameter	Fam	79	102842.5	1301.8	0.004 ***
Height	Fam	79	650168.9	8229.9	<0.001 ***
Biomass	Fam	79	30555694.6	386780.9	0.003 ***

Table 4. The best 8 of the 80 *L. leucocephala* families tested for diameter, height and biomass after 6 months in the field.

Rank	Population	Best 10% (family)	Value
Diameter (mm)			
1	Bali	40	69.5
2	Majalengka	27	58.6
3	Majalengka	17	56.8
4	Bali	39	55
5	Subang	3	54
6	Subang	9	53
7	Brebes	34	53
8	Bantul	73	52
Height (m)			
1	Kupang (cv. Tarramba)	52	2.38
2	Kupang (cv. Tarramba)	51	2.34
3	Brebes	32	2.29
4	Majalengka	27	2.26
5	Menado	45	2.25
6	Majalengka	20	2.22
7	Kupang (cv. Tarramba)	57	2.19
8	Bali	40	2.18
Biomass index ($d^2 \times ht$)			
1	Kupang (cv. Tarramba)	51	1,000
2	Kupang (cv. Tarramba)	52	964
3	Menado	45	851
4	Majalengka	20	729
5	Brebes	37	727
6	Kupang (cv. Tarramba)	57	709
7	Brebes	32	686
8	Majalengka	15	665

Family correlations (n = 80) between growth in the nursery and in the field were significant only for height (y = 0.05 x + 22.873; r = 0.308**).

Discussion

Environmental factors were relatively uniform in the nursery and in the field. Therefore, growth was assumed to be influenced more by genetic potential than by environmental conditions. Variations in terms of growth (diameter and height) both in the nursery and in the field were expected to optimize selection to achieve genetic gain during the improvement program. While some families showed promise in terms of diameter and others were outstanding in terms of height, wood biomass as indicated by the biomass index was most important and families, which scored well in this parameter, are of most interest. Some Indonesian populations and families were comparable with those from cv. Tarramba, which is known for its superior growth compared with other cultivars (Rengsirikul et al. 2011).

Significant correlations between heights of families in the nursery and in the field indicated that good height in the nursery might indicate good height in the field. Families with high ratings for biomass production will be evaluated in terms of wood volume and quality for energy at the appropriate age to supplement current growth assessments. Outstanding families will progress through the breeding program.

Acknowledgments

This work was funded and supported by The Center for Forest Biotechnology and Tree Improvement Research and Development. The authors are deeply grateful to the wood-energy team for their assistance and patience in undertaking this research.

References

(Note of the editors: All hyperlinks were verified 8 May 2019.)

Hendrati RL. 2016. Genetic improvement of *Calliandra calothyrsus* for qualified wood energy. In: Forestry research to support sustainable timber production and self-sufficiency in food, energy and water. Proceedings of the 3rd INAFOR (Indonesia Forestry Researchers) Workshop, Bogor, Indonesia, 21–22 October 2015. p. 535–543. bit.ly/2J7n6nz

Hendrati RL; Hidayati N. 2018. Sembilan populasi *Leucaena leucocephala* (Lam.) de Wit. asal Indonesia untuk pemuliaan kayu energi versus var. Tarramba. Jurnal Perbenihan Tanaman Hutan 6(1):15–30. doi: 10.20886/bptpth.2018.6.1.15-30

Rakos C. 2008. The heat market-key to the transformation of our energy system. ProPellets Austria, Wolfsgraben, Austria.

Rengsirikul K; Kanjanakuha A; Ishii Y; Kangvansaichol K; Sripichitt P; Punsuvon V; Vaithanomsat P; Nakamanee G; Tudsri S. 2011. Potential forage and biomass production of newly introduced varieties of leucaena (*Leucaena leucocephala* (Lam.) de Wit.) in Thailand. Grassland Science 57:94–100. doi: 10.1111/j.1744-697X.2011.00213.x

Sikkema R; Steiner M; Junginger M; Hiegl W; Hansen MT; Faaij A. 2011. The European wood pellet markets: Current status and prospects for 2020. Biofuels, Bioproducts and Biorefining 5:250–278. doi: 10.1002/bbb.277

Singh Y; Singh G; Sharma DK. 2010. Biomass and bio-energy production of ten multipurpose tree species planted in sodic soils of Indo-gangetic plains. Journal of Forestry Research 21:19–24. doi: 10.1007/s11676-010-0003-5

Spelter H; Toth D. 2009. North America's wood pellet sector. Research Paper FPL-RP-656. United States Department of Agriculture (USDA), Madison, WI, USA. bit.ly/2VlgAQx

Stewart JL; Salazar R. 1992. A review of measurement options for multipurpose trees. Agroforestry Systems 19:173–183. doi: 10.1007/BF00138507

(Accepted 8 May 2019 by the ILC2018 Editorial Panel and the Journal editors; published 31 May 2019)