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Growth performance of two bamboo species in new plantations

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Abstract—The growth performance of new stands of *Dendrocalamus asper* and *Gigantochloa levis* on marginal lands and fertilized with three organic fertilizers was assessed over a period of 4 years. The experimental site was in the UP Laguna-Quezon Land Grant in Real, Quezon, Philippines. The results have shown a very high survival (100%) rate and comparatively good growth and development of both species. The influence of the organic fertilizers on average number of shoot emergents, number of culms per clump, average height and culm diameter was only significant during the first year of plantation establishment. It is concluded that no statistically significant and consistent improvement in establishment of the clumps or growth and quality of the culms could be assigned to the effects of the organic fertilizers studied over the first four years of plantation establishment at this site.

Key words: *Dendrocalamus asper*; *Gigantochloa levis*; marginal land; organic fertilizer; shoot emergents; culms per clump.

INTRODUCTION

Bamboos are widely distributed, mainly in the tropical, subtropical and mild temperate zones of the world, with the tropical belt having the largest number of species. Worldwide, approximately 87 genera and over 1500 species of bamboos exist [1] and of these nearly 62 are found in the Philippines [2].

Intensified interest in bamboos has resulted in their emergence as potentially the most important non-timber forest resource to substitute wood. Their strength, straightness, lightness combined with extraordinary hardness, range in size, abundance, easy propagation and short vegetation period to attain maturity, make them

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suitable for a variety of purposes and uses [3]. Furthermore, bamboo as a woody plant is uniquely suited to agroforestry.

With its intensive utilization, bamboo is now an exploited plant and the supply of raw material has already decreased. In this regard, an improved knowledge of bamboo production plays an important role. There are several production techniques that can be employed to improve and increase sustainable yields. One of these is the application of either organic or inorganic fertilizers. Whereas there are several reports on the effects of inorganic fertilizers the knowledge about the organics is meagre. Hoanh [4] has observed that inorganic fertilizer application for *Bambusa blumeana* enhances growth and yield. In the Philippines a number of organic fertilizers are locally available, but the effect of these on bamboo plantation establishment and yields has not been scientifically investigated. Therefore, research was undertaken within the framework of the European Commission (EC) Project entitled 'Sustainable Management and Quality Improvement of Bamboos and Products' to assess the effect of three organic fertilizers on the productivity of *Gigantochloa levis* and *Dendrocalamus asper*, the result of which is reported in this paper.

MATERIALS AND METHODS

Materials

Two pachymorph bamboo species were used in the study, namely: *Dendrocalamus asper* (Schultes f.) Backer ex Heyne and *Gigantochloa levis* (Blanco) Merr. Culm cuttings were collected from the Makiling Forest Reserve, UPLB College of Forestry and Natural Resources in February and March of 1998.

Methods

Propagation and culture of the planting stocks in the nursery. Culms of approximately 1 to 2 years old were selected as the source of clones. Using sharp handsaws, they were divided into one-nodal culm cuttings with about 5–8 cm basal internode, 20–25 cm upper internode and one-nodal branch stub. Twelve culm cuttings were obtained from the upper portion of the culm from *G. levis* and *D. asper*. Immediately after collection, the cuttings were placed in a specially constructed mist propagation chamber. No rooting hormones were used. After two months *G. levis* and *D. asper* culm cuttings had achieved 64% and 75% rooting, respectively.

All rooted cuttings were potted in 18 cm × 18 cm × 28 cm poly-bags pre-filled with ordinary garden soil. The plants were maintained in the nursery for 3 to 4 months and then transported to the site in the UP Laguna-Quezon Land Grant area in Real, Quezon. The site has an area of 2.16 ha at an elevation of 500 to 530 m above sea level with rolling topography. It was formerly planted with coconut. The soil is very acidic, with low nutrient content, high water holding capacity and high bulk density (Table 1). It is characterized by the absence of dry season, with

Table 1.
Physical and chemical properties of the soil in the bamboo experimental site

Property	Area I *G. levis*	Area II *D. asper*
pH	4.8	4.8
Organic matter (%)	5.17	6.64
N (%)	0.18	0.19
P (ppm)	1.40	1.75
K (me/100g soil)	0.19	0.14
Ca (me/100g soil)	0.91	1.04
Mg (me/100g soil)	0.34	0.57
Na (me/100g soil)	0.53	0.51
CEC (me/100g soil)	27.78	27.78
Fe (ppm)	69.0	70.0
Zn (ppm)	7.1	7.1
Cu (ppm)	20.6	16.3
Mn (ppm)	8.2	7.0
Cl (ppm)	338.09	144.90
SO_4(ppm)	441.57	263.43
WHC (%)	96.60	101.73
MC (%)	11.70	11.08
Particle density (gm/cc)	2.86	2.84
Sand (%)	19.02	16.69
Silt (%)	22.34	27.77
Clay (%)	58.64	55.54
Textural grade	Clay	Clay
Bulk density	0.74	0.81

pronounced maximum rain period from October to December. The average total annual rainfall is approximately 4000 mm.

Fertilization regime. Potted rooted cuttings were nurtured and hardened in the nursery before they were out planted. A month before out planting, brushing and clearing were done. Each planting spot was staked and holes of 50 cm wide and 50 cm deep were prepared. As organic fertilizers, cow dung (CD), chicken manure (CM) and rice hull ash (RHA) were used. The chemical properties of said organic fertilizers are shown in Table 2. For each species, 3 fertilizers at 4 rates of application were replicated 4 times in the area. In each block, 3 subplots of the fertilizer types (CM, CD, RHA) were established. Each subplot was further subdivided into 4 sub-subplots which corresponded to the various rates of application. Before planting, a basal application of fertilizers was carried out to the planting hole. The rates were 0 kg, 0.5 kg, 1 kg and 2 kg per plant with a frequency once every two months in year one. During the second year, the fertilizers were applied quarterly at rates of 0 kg, 0.75 kg, 1.5 kg and 3 kg rates and in the third year, every six months at 0 kg, 1.5 kg, 3 kg and 6 kg rates. No fertilizer was applied in year 4.

Table 2.
Chemical properties of organic fertilizers

	Fertilizer		
	Chicken manure	Cow dung	Rice hull ash
pH	7.00	7.30	9.20
N (%)	1.08	1.33	0
P (%)	0.84	0.63	0.18
K (%)	1.23	0.89	0.39

The following data were collected: total number of shoots and developed culms, and their height and diameter. Measurements were made monthly for the first three years and once in year 4. The experimental data were collected between September 1998 and December 2002, respectively.

Statistical analysis

The Analysis of Variance (ANOVA) at $P = 0.05$ was used to determine if the difference between treatments were significant. The Duncan Multiple Range Test (DMRT) was used to compare means of the treatments.

RESULTS AND DISCUSSION

Effects of organic fertilizers on survival

All outplantings of both species developed into viable clumps (100% survival). This excellent survival can be attributed to the quality of the nursery stocks. Well hardened, high quality potted planting stocks, when field planted with their root ball intact, can easily survive even harsh conditions in planting sites [5].

Effects of organic fertilizers on shoot emergence

Figures 1 and 2 show the trends in shoot production of *G. levis* and *D. asper*, respectively. During the study period, a see-saw pattern with variable peaks and troughs in monthly averages for shoot emergence was found in all fertilizer treatments and the control. Bamboo shoots usually emerge during the rainy season and very few shoots arise during the dry season when soil moisture is at its lowest. According to Uchimura [6], vegetative growth of bamboos is affected more by soil moisture than by temperature. At the first splash of rain, usually in the latter part of May, new shoots emerge as a result of more moisture in the soil. The availability of soil moisture and the decrease in temperature during the rainy season influence the emergence of shoots. In our study, April was the month with lowest rainfall. Rainfall started to increase in May and shoot emergence tended to be at its maximum in June.

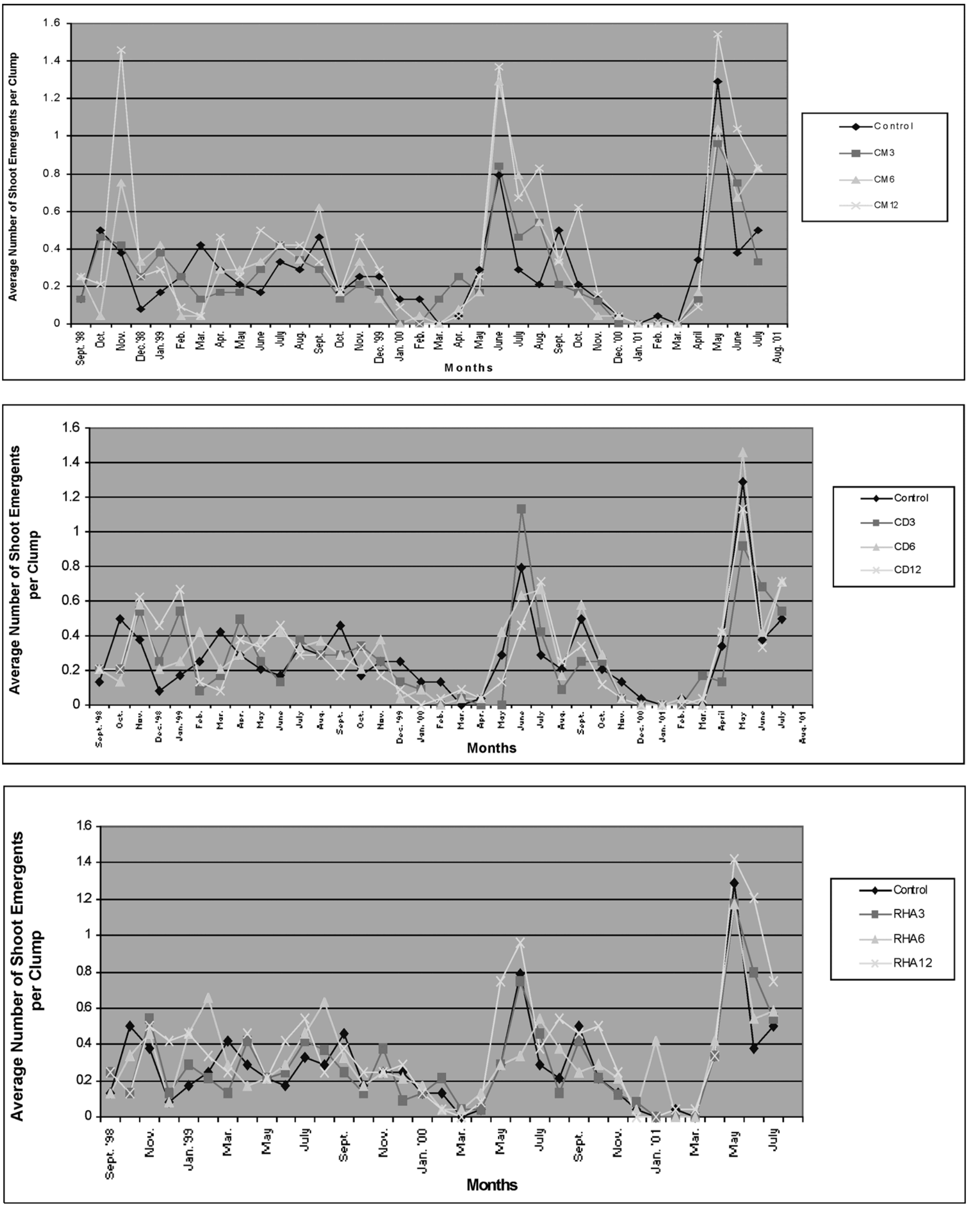

Figure 1. Top panel: monthly average number of shoots emerging per clump of *G. levis* with CM fertilizer. Middle panel: monthly average number of shoots emerging per clump of *G. levis* with CD fertilizer. Bottom panel: monthly average number of shoots emerging per clump of *G. levis* with RHA fertilizer.

Effects of organic fertilizers on the number of developed culms

Not all shoot emergents will ultimately develop into culms. In this study, the shoots that produced the first branch were recorded as developed culms.

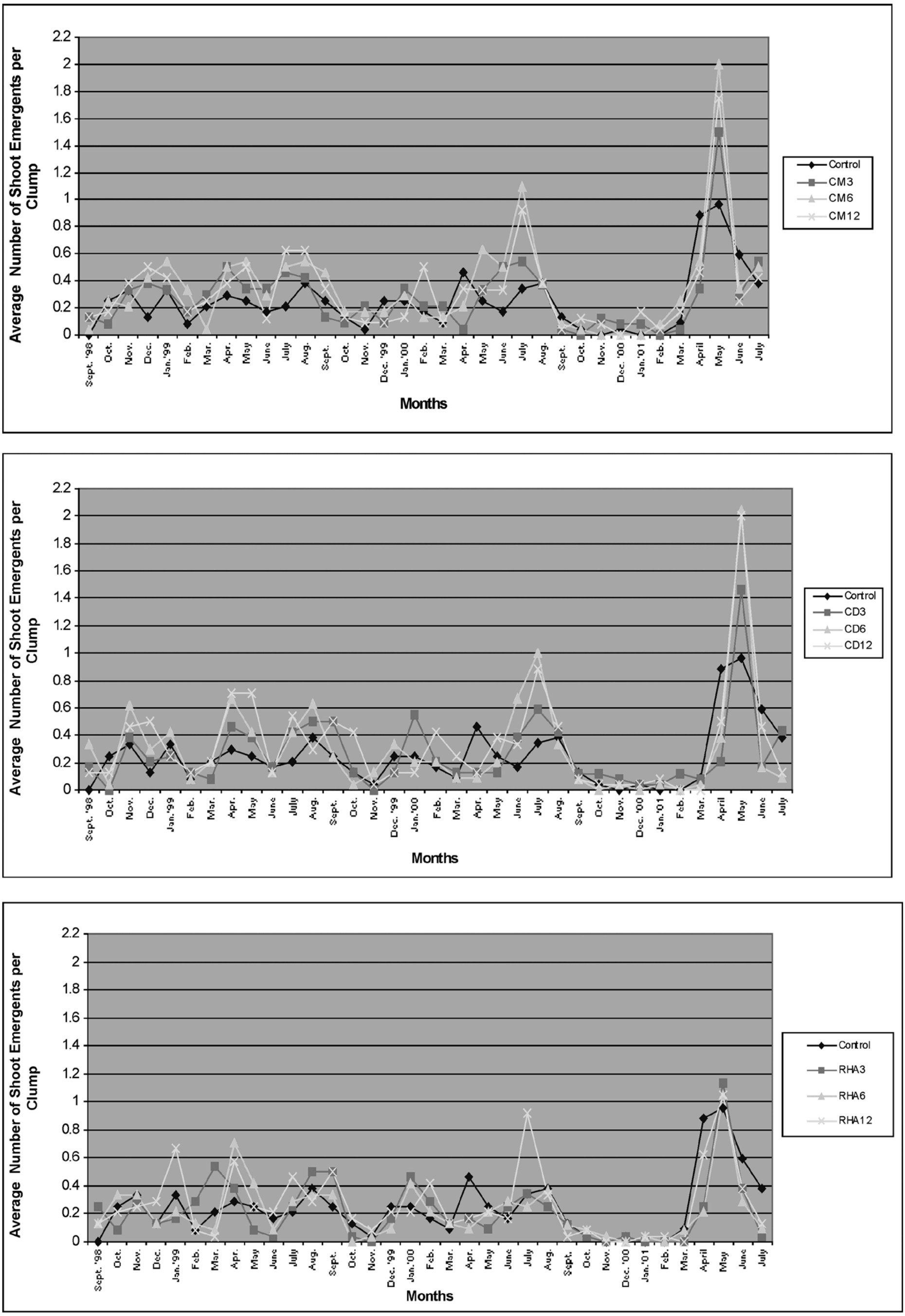

Figure 2. Top panel: monthly average number of shoots emerging per clump of *D. asper* with CM fertilizer. Middle panel: monthly average number of shoots emerging per clump of *D. asper* with CD fertilizer. Bottom panel: monthly average number of shoots emerging per clump of *D. asper* with RHA fertilizer.

Between 45 to 50 days were needed for the shoots to attain developed culms status. The three fertilizers made no difference to the normal, expected pattern of shoot emergence and onward growth into developed culms (Figs 3 and 4). Shoots took between 3 to 4 months to fully develop into culms. This pattern confirms the growth trend described by Suwannapinunt *et al.* [7], Maoyi *et al.* [8] and Uchimura [9].

Effects of organic fertilizers on the average number of shoot emergents and culms: height and diameter after 6 months, 1 year, 2 years, 3 years and 4 years

Average number of shoot emergents. In *G. levis*, significant differences in the effects of organic fertilizers on shooting were only manifested during the first 6 months and at two years but not at years 1, 3 and 4. No consistent significant improvement in the number of shoot emergents over unfertilised control clumps was therefore seen over the period of study, although the 12 kg CM treatment gave the highest average total number of shoot emergents (Table 3). Moreover, there was considerable variability in the data set, which meant that no statistical reliance could be placed on this. In *D. asper*, no significant differences in the effects of organic fertilizers on shoot emergents were observed at any time over the first 3 years. Again, no improvement over unfertilized clumps was observed. Among the individual treatments, the 6 kg CM gave the highest average number of shoot emergents (Table 3). However, there was high variability of the data and no consistent conclusion could be drawn.

Average number of culms. In *G. levis*, significant differences in the effects of organic fertilizers on the average number of culms occurred only during the first six months and the first year of plantation development and not in years 2, 3 and 4. Treatment with 12 kg RHA gave the highest average total number of culms per clump (Table 3). However, there is no significant difference on the total number of culms per clump among fertilizers and rates of application after four years of plantation. In *D. asper*, no significant differences on the effects of organic fertilizers on the average number of culms were observed in all the growth monitoring periods during the 4 years. Again, treatment with 6 kg CM gave the highest average total number of culms per clump (Table 3).

Average height and diameter of culms. In *G. levis*, no significant effects of organic fertilizers on height and diameter were observed in all the growth monitoring periods during the 4 years (Table 4). Also in *D. asper*, no significant effects of organic fertilizers on height were observed. The effects on diameter were not significant during the first six months, and in years 2, 3 and 4. Only for the first year the 12 kg CD resulted in bigger culms than the other treatments including the control. However, treatment with 12 kg CM gave the highest average total height and diameter, respectively (Table 4).

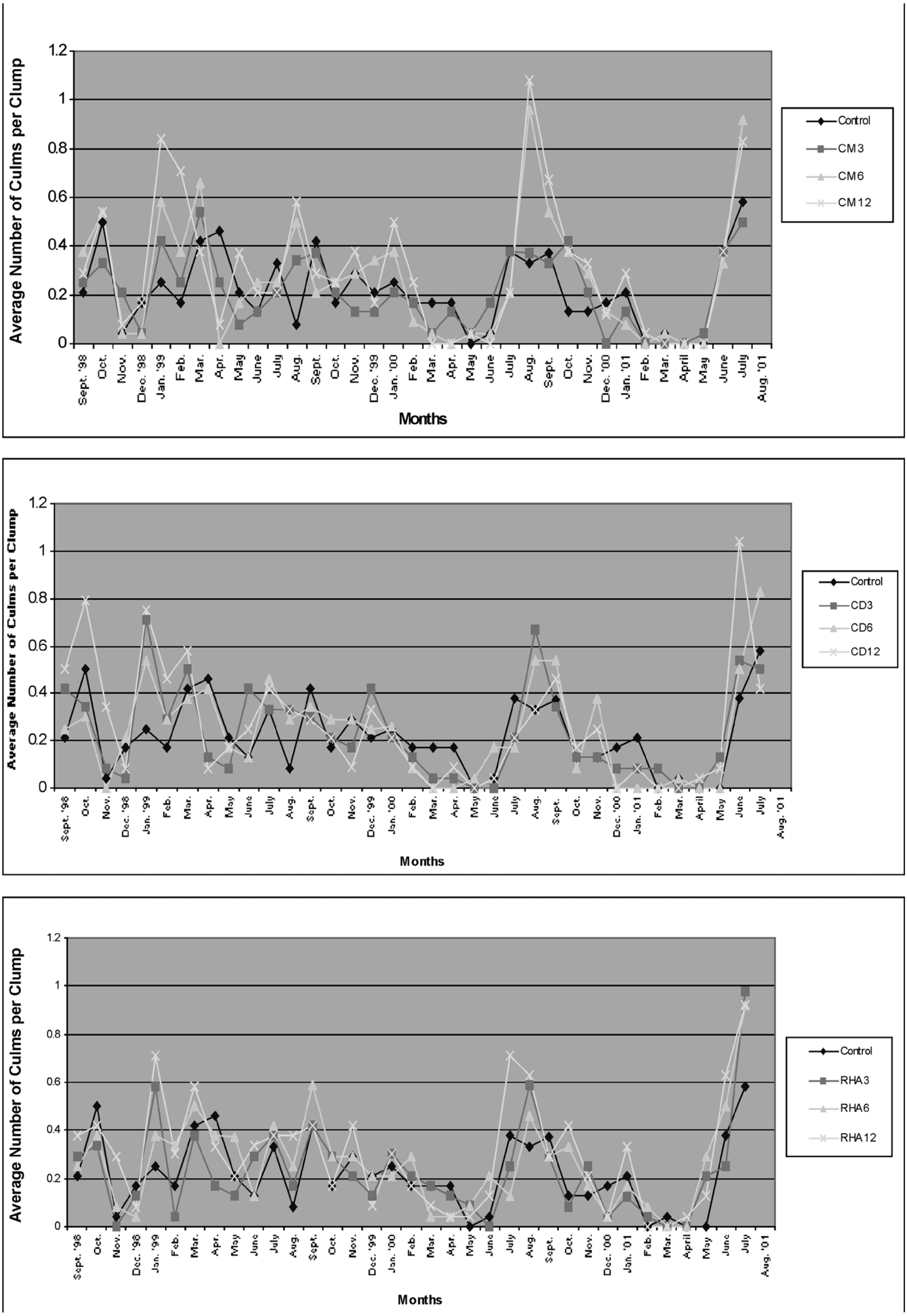

Figure 3. Top panel: monthly average number of culms per clump of *G. levis* with CM fertilizer. Middle panel: monthly average number of culms per clump of *G. levis* with CD fertilizer. Bottom panel: monthly average number of culms per clump of *G. levis* with RHA fertilizer.

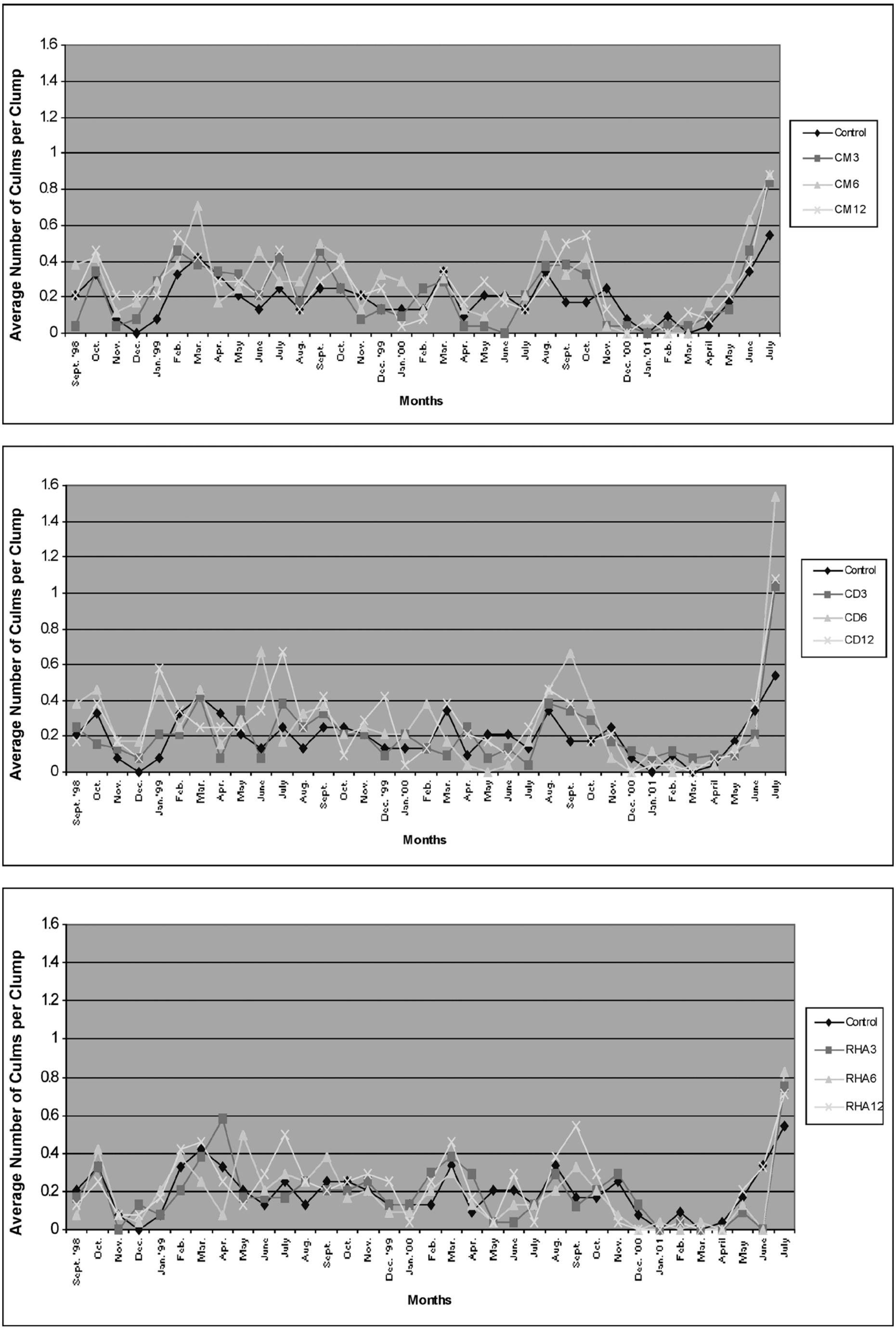

Figure 4. Top panel: monthly average number of culms per clump of *D. asper* with CM fertilizer. Middle panel: monthly average number of culms per clump of *D. asper* with CD fertilizer. Bottom panel: monthly average number of culms per clump of *D. asper* with RHA fertilizer.

Table 3.
Shoot and culm development of *G. levis* and *D. asper* after four years

Parameter	Treatment	6 months	1st year	2nd year	3rd year	4th year	Total
Average number of shoot emergents per clump of *G. levis*	Control	1.50^{b}	3.21^{a}	3.00^{ab}	3.25^{a}	3.88^{a}	13.34^{a}
	CM 3	1.88^{a,b}	3.50^{a}	3.17^{a,b}	2.71^{a}	3.63^{a}	13.00^{a}
	CM 6	1.84^{a,b}	3.71^{a}	4.25^{a,b}	3.33^{a}	4.34^{a}	15.63^{a}
	CM 12	**2.54**^{a}	**4.79**^{a}	**4.50**^{a}	4.67^{a}	5.71^{a}	**19.67**^{a}
	CD 3	1.84^{a,b}	3.75^{a}	2.75^{a,b}	2.96^{a}	3.84^{a}	13.30^{a}
	CD 6	1.79^{a,b}	4.04^{a}	2.96^{a,b}	3.58^{a}	4.21^{a}	14.79^{a}
	CD 12	2.29^{a,b}	4.38^{a}	2.58^{b}	3.13^{a}	3.38^{a}	13.46^{a}
	RHA 3	1.54^{b}	3.46^{a}	2.83^{a,b}	3.67^{a}	4.12^{a}	14.08^{a}
	RHA 6	2.13^{a,b}	3.79^{a}	2.84^{a,b}	3.54^{a}	3.71^{a}	13.88^{a}
	RHA 12	2.09^{a,b}	4.42^{a}	4.04^{a,b}	**5.00**^{a}	**6.13**^{a}	19.58^{a}
Average number of culms per clump of *G. levis*	Control	1.17^{c}	3.00^{b}	2.58^{a}	2.09^{a}	2.71^{a}	10.38^{a}
	CM 3	1.50^{c}	3.33^{b}	2.33^{a}	2.04^{a}	2.54^{a}	10.25^{a}
	CM 6	1.96^{a,b,c}	4.13^{a,b}	2.83^{a}	2.71^{a}	3.25^{a}	12.92^{a}
	CM 12	2.92^{a,b}	4.79^{a,b}	**3.17**^{a}	**3.04**^{a}	3.63^{a}	14.62^{a}
	CD 3	1.88^{b,c}	4.17^{a,b}	2.33^{a}	2.08^{a}	3.13^{a}	11.71^{a}
	CD 6	1.59^{c}	3.58^{a,b}	2.50^{a}	2.38^{a}	3.09^{a}	11.54^{a}
	CD 12	**2.63**^{a}	**5.38**^{a}	1.83^{a}	2.54^{a}	2.71^{a}	12.46^{a}
	RHA 3	1.38^{c}	3.17^{b}	2.79^{a}	2.25^{a}	2.71^{a}	10.92^{a}
	RHA 6	1.46^{c}	3.42^{b}	2.75^{a}	2.79^{a}	2.67^{a}	11.63^{a}
	RHA 12	2.17^{a,b,c}	4.88^{a,b}	**3.17**^{a}	3.00^{a}	**4.83**^{a}	**15.88**^{a}
Average number of shoot emergents per clump of *D. asper*	Control	0.84^{a}	2.88^{a}	3.08^{a}	2.5^{a}	1.96^{a,b,c}	9.71^{a}
	CM 3	1.26^{a}	3.88^{a}	3.13^{a}	3.05^{a}	2.25^{a,b,c}	12.45^{a}
	CM 6	1.76^{a}	4.29^{a}	**4.29**^{a}	**3.62**^{a}	2.96^{a,b}	**15.34**^{a}
	CM 12	1.83^{a}	4.33^{a}	3.67^{a}	3.58^{a}	**3.04**^{a}	14.83^{a}
	CD 3	1.05^{a}	3.29^{a}	3.25^{a}	3.08^{a}	2.17^{a,b,c}	11.88^{a}
	CD 6	**1.88**^{a}	**4.59**^{a}	3.54^{a}	3.58^{a}	2.50^{a,b,c}	14.42^{a}
	CD 12	1.71^{a}	4.29^{a}	4.04^{a}	3.54^{a}	2.54^{a,b,c}	14.50^{a}
	RHA 3	0.92^{a}	3.08^{a}	2.79^{a}	2.00^{a}	1.84^{a,b,c}	9.79^{a}
	RHA 6	1.22^{a}	3.21^{a}	2.46^{a}	2.00^{a}	1.63^{c}	9.42^{a}
	RHA 12	1.13^{a}	3.54^{a}	3.50^{a}	2.33^{a}	1.75^{b,c}	11.25^{a}
Average number of culms per clump of *D. asper*	Control	1.14^{a}	2.49^{a}	2.37^{a}	1.75^{a}	1.50^{a,b}	8.66^{a}
	CM 3	1.42^{a}	3.12^{a}	2.17^{a}	2.42^{a}	1.70^{a,b}	9.66^{a}
	CM 6	**1.79**^{a}	**4.29**^{a}	**3.29**^{a}	2.83^{a}	**2.34**^{a}	**13.17**^{a}
	CM 12	1.76^{a}	3.88^{a}	2.63^{a}	2.92^{a}	2.30^{a}	12.21^{a}
	CD 3	1.13^{a}	2.83^{a}	2.38^{a}	2.62^{a}	1.79^{a,b}	9.75^{a}
	CD 6	**1.79**^{a}	4.25^{a}	2.46^{a}	**3.17**^{a}	2.12^{a,b}	12.33^{a}
	CD 12	1.58^{a}	3.92^{a}	2.92^{a}	2.46^{a}	1.88^{a,b}	11.92^{a}
	RHA 3	1.22^{a}	2.84^{a}	2.38^{a}	1.88^{a}	1.46^{a,b}	8.84^{a}
	RHA 6	1.26^{a}	2.79^{a}	2.04^{a}	1.88^{a}	1.29^{b}	8.29^{a}
	RHA 12	1.63^{a}	3.09^{a}	2.46^{a}	2.29^{a}	1.46^{a,b}	9.67^{a}

Means with the same letter are not significantly different at $P = 0.05$. Values in bold represent the maximum value amongst the treatments.

Table 4.
Culm parameters of *G. levis* and *D. asper* after four years

Parameter	Treatment	6 months	1st year	2nd year	3rd year	4th year	Total
Average height (m) of culms of *G. levis*	Control	1.29^{a}	1.75^{a}	3.53^{a}	5.16^{a}	7.01^{a}	4.40^{a}
	CM 3	1.25^{a}	1.75^{a}	3.97^{a}	5.03^{a}	$\mathbf{7.35}^{a}$	$\mathbf{4.63}^{a}$
	CM 6	$\mathbf{1.42}^{a}$	1.84^{a}	3.93^{a}	5.15^{a}	6.61^{a}	4.42^{a}
	CM 12	1.40^{a}	$\mathbf{1.92}^{a}$	$\mathbf{4.19}^{a}$	$\mathbf{5.22}^{a}$	6.49^{a}	4.51^{a}
	CD 3	1.24^{a}	1.73^{a}	3.85^{a}	4.55^{a}	5.54^{a}	3.99^{a}
	CD 6	1.31^{a}	1.82^{a}	3.87^{a}	5.12^{a}	6.11^{a}	4.23^{a}
	CD 12	1.21^{a}	1.65^{a}	3.71^{a}	4.72^{a}	6.15^{a}	4.11^{a}
	RHA 3	1.07^{a}	1.61^{a}	3.57^{a}	4.74^{a}	6.12^{a}	4.07^{a}
	RHA 6	1.32^{a}	1.78^{a}	3.38^{a}	4.23^{a}	5.77^{a}	3.83^{a}
	RHA 12	1.27^{a}	1.74^{a}	3.80^{a}	4.28^{a}	5.27^{a}	3.81^{a}
Average diameter (cm) of culms of *G. levis*	Control	0.94^{a}	1.22^{a}	2.76^{a}	3.98^{a}	5.39^{a}	3.38^{a}
	CM 3	0.95^{a}	1.28^{a}	2.97^{a}	4.03^{a}	$\mathbf{5.49}^{a}$	3.50^{a}
	CM 6	1.03^{a}	1.33^{a}	3.14^{a}	4.21^{a}	5.18^{a}	3.50^{a}
	CM 12	1.07^{a}	$\mathbf{1.41}^{a}$	$\mathbf{3.45}^{a}$	$\mathbf{4.35}^{a}$	5.47^{a}	$\mathbf{3.71}^{a}$
	CD 3	0.92^{a}	1.26^{a}	3.10^{a}	4.05^{a}	4.39^{a}	3.21^{a}
	CD 6	1.02^{a}	1.38^{a}	3.14^{a}	4.31^{a}	4.98^{a}	3.46^{a}
	CD 12	0.90^{a}	1.22^{a}	3.14^{a}	4.03^{a}	4.79^{a}	3.30^{a}
	RHA 3	**1.14 a**	1.21^{a}	2.91^{a}	4.04^{a}	5.03^{a}	3.32^{a}
	RHA 6	0.92^{a}	1.24^{a}	2.79^{a}	3.80^{a}	4.91^{a}	3.21^{a}
	RHA 12	0.92^{a}	1.37^{a}	3.39^{a}	4.04^{a}	4.75^{a}	3.43^{a}
Average height (m) of culms of *D. asper*	Control	1.38^{a}	1.89^{a}	3.85^{a}	5.10^{a}	$6.60^{a,b}$	4.36^{a}
	CM 3	1.78^{a}	2.27^{a}	4.23^{a}	5.49^{a}	$7.12^{a,b}$	4.79^{a}
	CM 6	1.43^{a}	2.18^{a}	4.77^{a}	6.11^{a}	$7.38^{a,b}$	5.12^{a}
	CM 12	1.60^{a}	2.20^{a}	$\mathbf{5.27}^{a}$	$\mathbf{6.28}^{a}$	$\mathbf{9.03}^{a}$	$\mathbf{5.70}^{a}$
	CD 3	1.46^{a}	2.14^{a}	4.11^{a}	5.17^{a}	$7.07^{a,b}$	4.63^{a}
	CD 6	1.55^{a}	2.10^{a}	4.37^{a}	5.59^{a}	$7.17^{a,b}$	4.81^{a}
	CD 12	$\mathbf{1.85}^{a}$	$\mathbf{2.38}^{a}$	4.83^{a}	5.95^{a}	$7.44^{a,b}$	5.20^{a}
	RHA 3	1.45^{a}	2.09^{a}	4.23^{a}	5.34^{a}	$6.71^{a,b}$	4.61^{a}
	RHA 6	1.28^{a}	1.94^{a}	3.72^{a}	4.90^{a}	$6.46^{a,b}$	4.28^{a}
	RHA 12	1.52^{a}	2.14^{a}	4.34^{a}	5.06^{a}	6.37^{b}	4.49^{a}
Average diameter (cm) of culms in *D. asper*	Control	0.94^{a}	1.16^{c}	2.50^{a}	4.11^{a}	5.89^{a}	3.42^{a}
	CM 3	$\mathbf{1.23}^{a}$	$1.47^{a,b}$	3.29^{a}	4.96^{a}	6.34^{a}	4.02^{a}
	CM 6	1.05^{a}	$1.45^{a,b}$	3.66^{a}	5.44^{a}	6.76^{a}	4.34^{a}
	CM 12	1.07^{a}	$1.39^{a,b,c}$	$\mathbf{4.03}^{a}$	$\mathbf{5.47}^{a}$	$\mathbf{7.58}^{a}$	$\mathbf{4.64}^{a}$
	CD 3	1.11^{a}	$1.41^{a,b}$	2.89^{a}	4.29^{a}	6.35^{a}	3.76^{a}
	CD 6	1.00^{a}	$1.36^{b,c}$	3.24^{a}	4.86^{a}	6.39^{a}	3.96^{a}
	CD 12	1.35^{a}	$\mathbf{1.62}^{a}$	3.84^{a}	5.13^{a}	6.70^{a}	4.39^{a}
	RHA 3	0.97^{a}	$1.33^{b,c}$	2.90^{a}	4.57^{a}	6.00^{a}	3.69^{a}
	RHA 6	0.93^{a}	$1.32^{b,c}$	2.59^{a}	4.53^{a}	6.23^{a}	3.70^{a}
	RHA 12	1.00^{a}	$1.36^{b,c}$	3.29^{a}	4.72^{a}	5.99^{a}	3.85^{a}

Means with the same letter are not significantly different at $P = 0.05$. Values in bold represent the maximum value amongst the treatments.

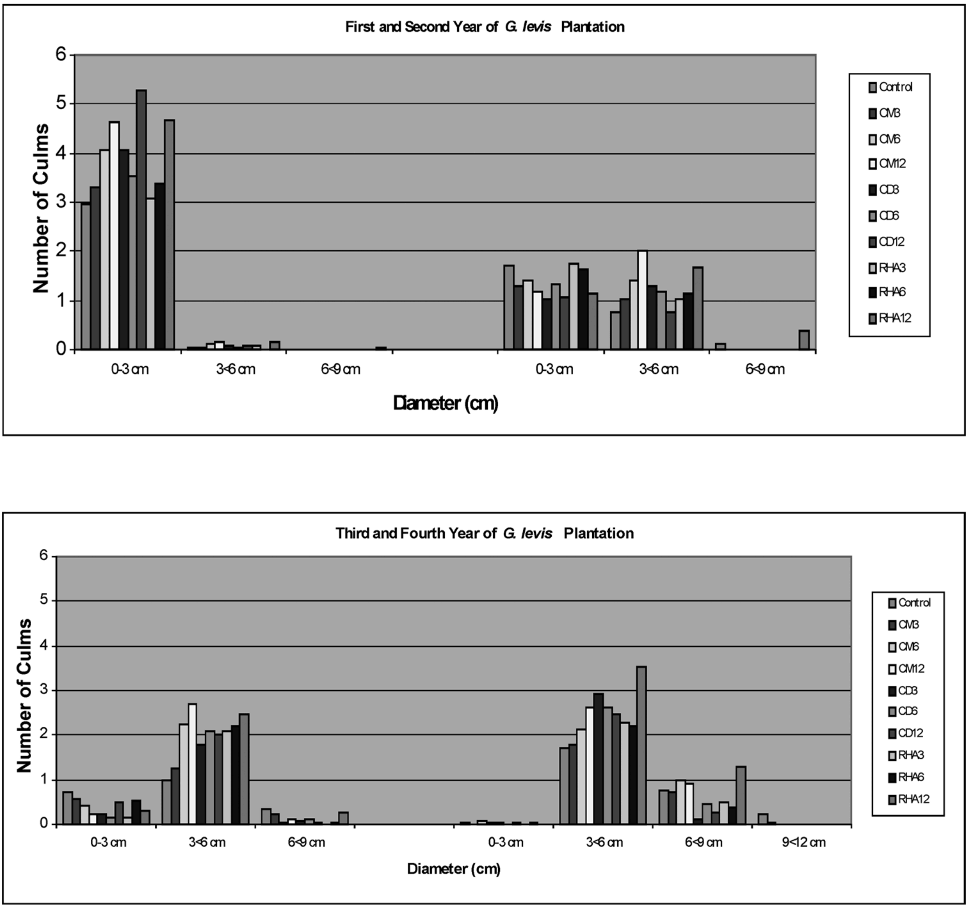

Figure 5. Culm production per clump per year of *G. levis* based on diameter classes.

Successional growth of culms. Figures 5 and 6 show the successional growth pattern of *G. levis* and *D. asper*, respectively. Profuse shooting in all treatments, including the control, occurred in the first year with most culms being of diameter class < 3 cm and few in diameter class of 3 to 6 cm.

During the second year, culms of *G. levis*, for all treatments including the control, were almost equally distributed between the diameter classes of <3 cm and 3–6 cm. For *D. asper*, however, the most common diameter classes were <3 cm, then 3–6 cm diameter and a few in the 6–9 cm class. In the third and fourth years after plantation establishment culms of 6–9 cm and 9–12 cm became common. This demonstrates the move from a juvenile state of clumps towards a mature and harvestable state by the fourth year. However, these culms are of little commercial value for harvesting at this time (not matured) and are best left to support on-going development of the clump for a further three to four years.

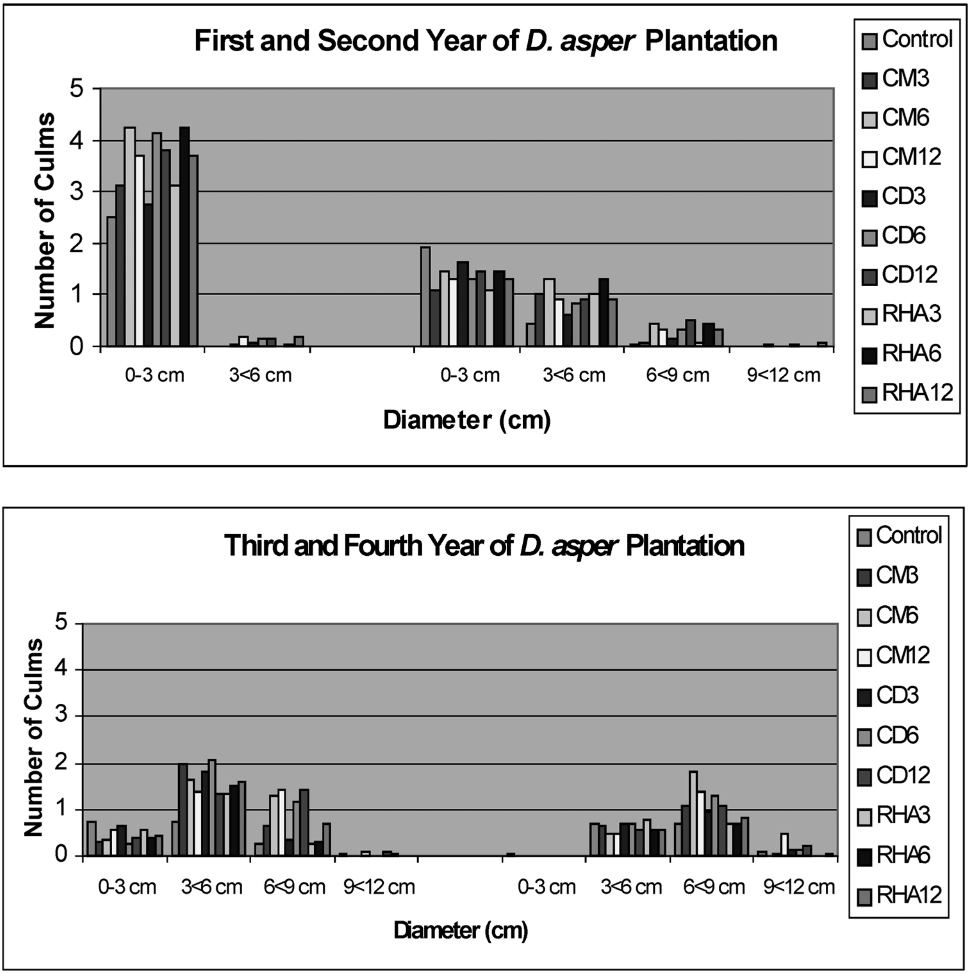

Figure 6. Culm production per clump per year of *D. asper* based on diameter classes.

By the fourth year after plantation establishment, most culms of *G. levis* were still in diameter class of 3–6 cm with some in the 6–9 cm class. In *D. asper*, the greatest proportion of culms had achieved a diameter of 6–9 cm and some were up to the 9–12 cm class (Figs 5 and 6).

DISCUSSION AND CONCLUSIONS

The production of high quality, vegetatively propagated, planting materials of *G. levis* and *D. asper* is possible using a mist-propagation chamber. It is possible to convert marginal land, such as an unproductive coconut plantation, into productive land using these two bamboo species. The high survival (100%) and comparatively good growth and development of both species in the field, with or without organic

Table 5.
Physico-chemical properties of soil in *G. levis* and *D. asper* plantation site

Soil	*G. levis* 1998 (before fertilization)	*G. levis* 2001				*D. asper* 1998 (before fertilization)	*D. asper* 2001			
		Control	CM	CD	RHA		Control	CM	CD	RHA
pH	4.80	4.80	5.27	5.23	4.67	4.80	4.90	4.90	5.10	4.80
N (%)	0.18	0.35	0.40	0.43	0.38	0.19	0.30	0.36	0.38	0.39
P (ppm)	1.40	1.00	98.67	30.33	5.67	1.75	1.00	62.33	33.67	6.67
K (me/ 100 g soil)	0.19	0.21	1.75	1.09	0.53	0.14	0.20	1.30	0.84	0.49
Organic matter (%)	5.17	7.00	8.03	8.50	7.60	6.64	6.0	7.17	7.57	7.63

fertilizer treatments, proved that these species can be grown in high elevation areas with acidic soil, particularly if there is well distributed rainfall throughout the year.

The influence of the three organic fertilizers tested on the growth and development of both bamboo species was only significant during the first year of plantation establishment, but not later. It should be noted that, whilst statistically significant differences could not be found in the data, some fertilizer treatments showed a tendency to increase the number of shoots and culms and increased culm height and diameter of both species. Organic fertilizers not only provided nutrients but also improved the physical properties of the soil (Table 5). The effect may become more pronounced when applied continuously for a long period of time. The data showed considerable variation between plots and replicates. We have concluded, within the range of experimental error and natural variability in the growth of these bamboo species at our site, that no statistically significant and consistent improvement in the growth of the clumps could be assigned to the effects of organic fertilizers. This suggests that the expense of fertilizer application and the labour involved would have been of no economic benefit in terms of improved establishment of the clumps or in production and quality of the culms produced in the early phase of plantation management. It is conceivable that under different conditions of site, soil or fertilizer application rates that different results might be obtained. However, recent work by Azmy [10] with compound fertilizer application in natural stands of *G. scortechinii* also indicated no overall benefit from the treatment.

Three years after plantation establishment culms more than 6 cm in diameter developed in both species. This suggests that by the sixth or seventh year after planting commercial harvesting of mature culms would be possible.

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