Growth and Fodder Yield of the *Gliricidia sepium* Provenances in Guardrow System in Dryland Farming Area in Bali, Indonesia

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ABSTRACT : A field experiment was carried out on a dryland farming area of southern Bali for 92 weeks, to study the growth and fodder yield of 16 provenances of *Gliricidia sepium* in guardrow system. The experimental design was completely randomized blocks of 16 treatments (*Gliricidia sepium* provenances) replicated 3 times, with 6 plants per provenance. Six provenances were from Mexico (M), four from Guatemala (G), and one each from Colombia (C), Indonesia (I), Nicaragua (N), Panama (P), Costa Rica (R) and Venezuela (V). After 40 weeks establishment the gliricidia were lopped 4 times a year at 150 cm height, at 2 months intervals during the 4 month wet season and 4 month intervals during the 8 month dry season. Stem elongation varied from 21 to 81 cm, leaf retention from 39 to 240%, branch number from 12 to 35, fodder yield from 1,090 to 3,153 g DW/plant, and wood yield from 743 to 2,750 g DW/plant. Pontezuelo provenance of Colombia (C24), Belen provenance of Nicaragua (N14) and Retalhuleu provenance of Guatemala (G14) were ranked first, second and third, respectively, for stem elongation, leaf retention, fodder and wood yields, during the wet and dry seasons.
(Key Words : Gliricidia Provenances, Seasonal Variation, Branch Distribution, Leaf Retention, Shoot Yield, Fodder Supply)

INTRODUCTION

In smallholder dryland farming areas including the sloping land area, food crops are mainly grown rather than livestock production. However, 29 to 49% of the farmer's income comes from livestock farming (Putra and Arga, 1979). In these drought prone areas forage is abundant during the wet season, but in the dry season is in short supply. Planting gliricidia below the terrace at 1 m plant spacings could prevent soil erosion during the rainy season, and could increase supply of cattle feed during the dry season as was shown in a three strata forage system experiment (Nitis et al., 1989).

Recently *G. sepium* has become popular as an alternative to *Leucaena leucocephala* due to its resistance to the defoliating psyllid (*Heteropsylla cubana*) which has devastated *L. leucocephala* in many parts of the tropics (Brewbaker, 1987; Simons and Stewart, 1994). Its superiority covers characteristics such as fast-growth, nitrogen fixation, nitrogen rich levels, tolerance to pruning, ability to copice vigorously, good fodder value, high foliage productivity and a vigorous tap root (Atta-Krah and Sumberg, 1987). Moreover, gliricidia can grow in various parts of the tropical zone from sea level to about 1,100 m elevation with mean annual rainfall of 650-3,500 mm and mean annual temperature range of 22-30℃ (Hughes, 1987).

The utilization of gliricidia fodder for farm animals has been tested in Central America, Africa and Asia (Devendra, 1990). It has also been tested in a three strata forage system (Nitis et al., 1989) and in the alley cropping system (Sukanten et al., 1995c).

Growth and yield of gliricidia is affected to a varying degrees by frequency and interval of cutting (Glover, 1987), association with other plant species (Nitis et al., 1989), plant density (Ella et al., 1989), topography, land utilization and climatic zones (Nitis et al., 1980), and provenances within the species (Nitis et al., 1991).

Oxford Forestry Institute (OFI), United Kingdom, has collected and preserved 29 provenances (accessions) of *G. sepium* from eight Latin American Countries covering different harvest times, altitude, latitude, rainfall, temperature and soils (Hughes, 1987). The result of 150 trials carried out in the tropics showed that there were marked differences among the provenances in biomass

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production within and between sites (Simons and Dunsdon, 1992). However, the Retalhuleu provenance from Guatemala showed stable and superior fodder and wood productions across a wide range of sites.

This paper describes the establishment, growth and yield during the wet and dry seasons, of 16 provenances of *Gliricidia sepium* grown as guardrow in dryland farming area in Bali, Indonesia.

MATERIALS AND METHODS

Location

The experiment was located in the dryland farming area at Bukit Peninsula of southern Bali (8° 45′ -8° 49′ S; 115° 5′ -115° 13′ E), Indonesia, at 100 m elevation and 3° sloping gradient. The soil was classified as red-brown Mediteran type with 10-25 cm soil depth, calcareous-based limestone with pH varying from 7.2-8.4 (Nitis et al., 1989). The mean daily temperature varied from 25 to 29℃ and relative humidity from 65 to 86%. The average annual rainfall was 1,681 mm with 96 rainy days in the wet season (December to March) and dry season (April to November).

Gliricidia sepium provenance seeds

The 15 *Gliricidia sepium* provenances supplied by Oxford Forestry Institute (OFI) were collected from seven Latin American Countries. Altitude varied from 0-1,100 m and annual rainfall from 650-3,500 mm (table 1). One provenance (I) was collected from Bukit peninsula, Bali. Of the 15 other provenances, six were from Mexico (M), four were from Guatemala (G), one each was from Colombia (C), Nicaragua (N), Panama (P), Costa Rica (R) and Venezuela (V). *Gliricidia sepium* seedlings were raised in the nursery for 8 weeks.

Table 1. Particulars of the 16 *Gliricidia sepium* provenances

Provenance code	Origin		Time of harvest (19..)	Altitude (m)	Rain fall (mm)	Temperature (℃)	Soil
	Country	Site					
G13	Guatemala	Volcan	84	950	1,060	22.5	Sandy loam
G14	Guatemala	Retalhuleu	84	330	3,500	27.5	Sandy gravel
G15	Guatemala	Gualan	84	150	700	26.8	Very sandy
G17	Guatemala	Monterrico	84	5	1,650	27.1	Saline sand
M33	Mexico	Los Amates	85	1,100	650	24.6	Regosol
M34	Mexico	Palmasola	85	10-50	1,130	27.5	Regosol
M35	Mexico	SanMateo	85	10-30	950	27.2	Unstratified sand
M38	Mexico	Playa Azul	85	0-30	900	27.5	Coarse regosol
M39	Mexico	SanJose	85	30	1,400	27.5	Unstratified regosol
M40	Mexico	Arriaga	85	30	1,796	27.6	Alluvial
V 1	Venezuela	Mariara	86	520	800	24.6	Deep black clay
R12	Costa Rica	Playa	86	0-10	1,927	24.8	Saline sand
R13	Panama	Pedasi	86	0-20	860	26.7	Drained sand
N14	Nicaragua	Belen	86	75	1,650	26.6	Heavy clay
C24	Colombia	Pontezuelo	86	20-50	950	27.7	Black vertisol
I	Indonesia	Bukit Bali	87	0-150	1,000	27	Red Brown Mediteran

[1] Adapted from Nitis et al. (1991)

Design

The four guardrow lines were established on a sloping plot of 3° gradient, so that the plot was devided equally into 3 areas (as blocks), consisted of upper (block III), middle (block I) and lower (block II) area (figure 1). Each block was partitioned by two guardrows pependicular to the sloping gradient. The guardrows between block I and II and block I and III was separated by 1 m width terrace. The 16 *Gliricidia sepium* provenances (as treatments) were randomly assigned in each block. Each block consisted of two 48 m rows with 20 m spacing between rows. Each row consisted of 8 provenances and each provenance occupied a row of 6 m length. Each provenance consisted of 6 plants with 1 m spacing between plants.

Observation

Eight week old gliricidia seedlings were transplanted to the field in the early wet season. Eight weeks after transplanting, the gliricidia were thinned into one plant per

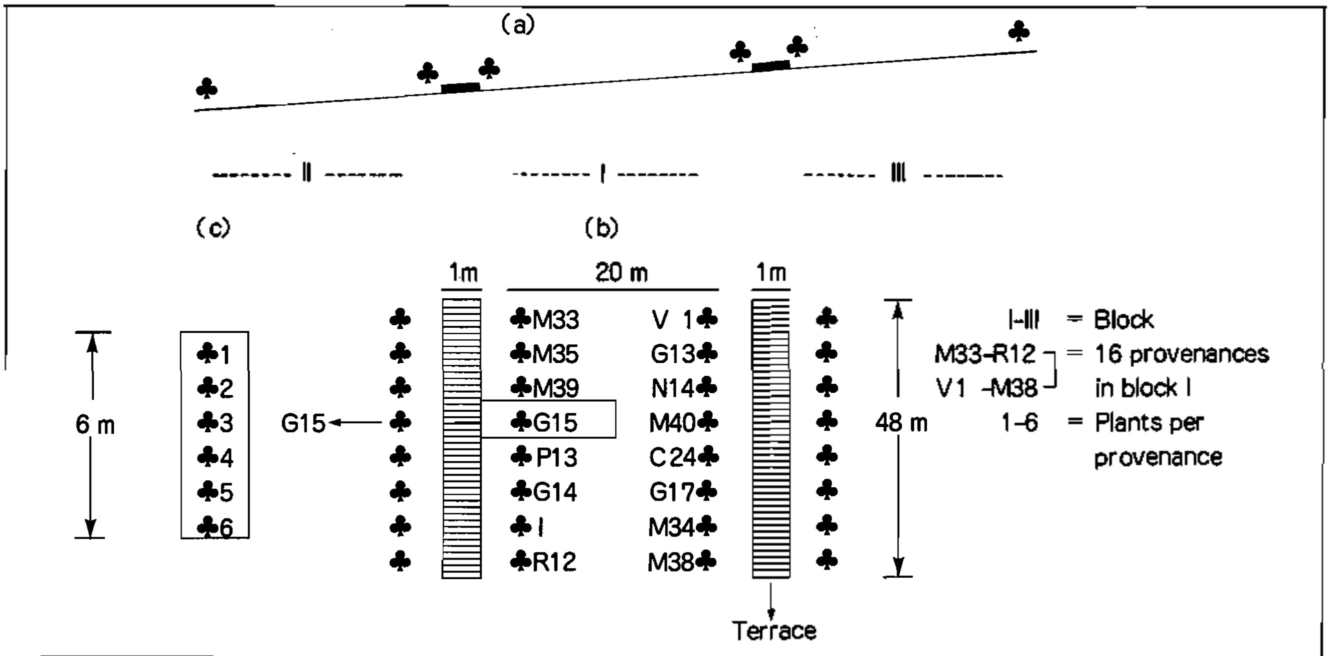

Figure 1. Allocation of the blocks (a), the 16 provenances (♣) in block I (b) and number of plants per provenance (c).

hill; and were left to establish for 40 weeks. At the first harvest, near the end of the dry season, each plant was lopped to 150 cm height and the branches lopped at 25 cm, from both sides of the gliricidia row. Subsequent lopping was carried out regularly 4 times a year, twice during the wet season (January and March) and twice during the dry season (July and November). Number of primary branches at 30, 60, 90 and 150 cm height were recorded at the same time. Sub samples of branch and leaf rachis were dried in forced draught oven at 70℃ to constant dry weight (DW).

The 92 week experiment consisted of 40 wk of growth and 52 production.

Statistical analysis

Data were analyzed by analysis of variance and when treatment differences were significant ($p < 0.05$) the new Duncan multiple range test (Steel and Torrie, 1960) was applied.

RESULTS AND DISCUSSION

Stem elongation among the provenances in the guardrow system were highly variable (table 2). It ranged from 26-77 cm during the 4 months wet season to 21-81 cm during the 8 months dry season. Stem of some provenances grew more during the wet season and some grew less during the wet season, than during the dry season; others exhibited similar stem elongation during both seasons. During the wet season M38 produced the

Table 2. Stem elongation of *G. sepium* provenances during the wet and dry seasons in the guardrow system

Provenance code	Stem elongation[1] Wet season Dec. '87 to March '88 I – II	Dry season April to Nov. '88 I – II
	.... cm	....
G13	47.06^{a} [2]	72.81^{a}
G14	30.94^{a}	63.61^{abc}
G15	65.64^{a}	72.62^{a}
G17	44.56^{a}	42.62^{abc}
M33	57.42^{a}	37.50^{abc}
M34	26.82^{a}	27.61^{bc}
M35	56.73^{a}	21.77^{c}
M38	77.33^{a}	70.94^{ab}
M39	55.83^{a}	24.82^{c}
M40	47.13^{a}	61.68^{abc}
V 1	61.25^{a}	27.16^{bc}
R12	41.73^{a}	47.83^{abc}
R13	41.06^{a}	25.05^{c}
N14	66.56^{a}	80.63^{a}
C24	48.17^{a}	55.14^{abc}
I	44.14^{a}	74.89^{a}
Mean ± SD	50.77 ± 13.29	50.42 ± 21.08
SEM[3]	9.33	13.11

[1] II-I.
[2] Values in the same column with different superscripts differed ($p < 0.05$).
[3] SEM = Standard error of the treatment means.

longest stem and M34 the shortest, while during the dry season N14 and M35 produced the longest and the shortest stems, respectively. The mean values (±SD) of the stem elongation over all provenances were 50.77 ± 13.29 cm and 50.42 ± 21.08 cm during the wet and dry seasons, respectively.

As expected, leaf number retained during the wet season was more than in the dry season (table 3). During the dry season, the rate of leaf shedding was faster than the leaf emergence so that negative values were obtained for some provenances. During the wet season the leaf retention varied from 130 to 240%, and in the dry season from −39 to 45%. During the wet season M35 retained the highest leaf percentage; while during the dry season G14 was highest. During both seasons M34 retained the lowest leaf percentage. It is of interest to note that N14 have the highest stem elongation and G14 the highest leaf retention during the dry season. This indicates that N14 and G14 have genetic capability to adapt quickly the new environment, despite coming from areas with higher annual rainfall (see table 1).

During 12 months growth, branch number was highest for G14 and lowest for M34, varying from 12 to 35 branches over all provenances (table 4). In terms of branch distribution G14, M35 and M39 produced more branches at the bottom (0-30 cm); P13, G15 and M38

Table 3. Leaf retained by *G. sepium* provenances during the wet and dry seasons in the guardrow system

Provenance code	Leaf retained[1)]	
	Wet season Dec. '87 to March '88 (I → II)	Dry season April to Nov. '88 (I → II)
	.... %	
G13	197.07	11.45
G14	170.80	44.64
G15	201.54	−15.79
G17	229.16	−38.53
M33	170.96	−31.02
M34	130.93	−38.57
M35	239.97	−25.78
M38	204.68	−25.49
M39	202.21	12.81
M40	175.63	19.10
V 1	220.02	−12.45
R12	184.24	1.25
R13	179.13	−12.98
N14	198.59	18.34
C24	217.01	3.04
I	142.58	17.81
Mean ± SD	191.53 ± 29.52	−4.52 ± 24.23

1) $\frac{II-I}{I} \times 100\%$

Table 4. Branch number and distribution at 12 months growth of *G. sepium* provenances in the guardrow system

Provenance code	Branch location in the stem (cm from the ground)				Whole plant (Total)
	0-30	30-90	90-150	>150	
G13	0.33	5.17	6.58	10.00	22.08^{abcde} [1)]
G14	2.25	6.08	6.17	20.08	34.58^{a}
G15	0.50	3.67	3.75	10.17	18.09^{cde}
G17	2.42	6.33	9.58	12.58	30.91^{abc}
M33	0.42	1.75	3.33	8.33	13.83^{de}
M34	0.33	2.25	1.75	8.00	12.33^{e}
M35	1.33	4.08	4.58	11.08	21.07^{bcde}
M38	0.42	3.67	3.83	16.75	24.67^{abcde}
M39	0.92	4.00	4.58	13.33	22.83^{abcd}
M40	1.25	5.42	7.08	12.42	26.17^{abcd}
V 1	0.58	3.33	4.42	16.58	24.91^{abcde}
R12	1.25	4.42	5.50	12.42	23.59^{abcde}
P13	0.42	4.83	5.92	15.66	26.83^{abcd}
N14	0.92	4.08	5.00	15.50	25.50^{abcd}
C24	1.33	5.50	8.42	17.42	32.67^{ab}
I	0.67	3.33	4.50	17.42	25.92^{abcd}
Mean ± SD	0.96 ± 0.65	4.24 ± 1.28	5.31 ± 1.96	13.73 ± 3.57	24.12 ± 6.02
SEM[2)]	–	–	–	–	3.89

[1)] Values in the same column with different superscripts differed ($p < 0.05$).

[2)] SEM = Standard error of the treatment means.

produced more branches at the middle (30-90 cm); C24, M40 and G13 produced more branches at the top (90-150 cm); while the other provenances produced even branch distribution from bottom to the top. Puger et al. (1993) suggested that the provenances with more branches at the bottom might be more effective at controlling weeds, while those with more branches in the middle might be best as wind breaks; those with more top branches could provide best support for estate crops, while those evenly branched could make the best live fence. The present experiment also identifies considerable variation in the characteristics of provenances despite the different specificity of the provenances for such functions to those described by Puger et al. (1993).

The mean(±SD) values of leaf and branch yields were 50.20 ± 28.45 and 40.91 ± 31.34 g DW/plant, respectively; with the higher shoot (leaf + branch) yield of the N14 at first lopping of 40 weeks old after transplanting was due to its superior branch and leaf components (table 5). N14 also had high stem elongation during both wet and dry seasons, with good leaf retention during the dry season and high branch number. Previous trials have shown N14 to be the highest ranking in terms of shoot yield when grown in alley cropping (Sukanten et al., 1995a) and fence systems (Sukanten et al., 1995b). The other 2 promising provenances were C24 and G17, ranking second and third, respectively, for shoot yield after 40 weeks establishment.

Table 5. Yields of *G. sepium* provenances at the end of the 40 weeks establishment in the guardrow system

Provenance code	Yields		
	Leaf	Branch	Shoot (Leaf+ Branch)
	.... g DW/plant		
G13	68.74	43.35	112.09[bc 1)]
G14	45.58	21.22	66.80[bc]
G15	58.45	53.94	112.39[bc]
G17	97.26	45.31	142.57[ab]
M33	29.74	28.59	58.33[cd]
M34	22.59	4.59	27.18[d]
M35	14.47	3.46	17.93[d]
M38	62.60	70.20	132.80[ab]
M39	38.38	28.83	67.21[bc]
M40	62.69	58.95	121.64[ab]
V 1	44.98	40.31	85.29[bc]
R12	30.55	20.25	50.80[cd]
R13	1.06	0.75	1.81[e]
N14	109.31	127.05	236.36[a]
C24	83.02	62.64	145.66[ab]
I	41.77	45.14	86.91[bc]
Mean ± SD	50.20±28.45	40.91±31.34	91.61±58.66
SEM[2)]	–	–	37.78

[1)] Values in the same column with different superscripts differed ($p < 0.05$).

[2)] SEM = Standard error of the treatment means.

C24 produced the highest annual fodder yield and M34 the lowest, while over all provenances yields ranged from 1,090 to 3,153 g DW/plant (table 6). However, for strategic lopping, C24 produced the highest leaf during the early wet season, while P13 produced the lowest. During the late wet season, G14 produced the highest leaf yield while M33 produced the lowest. C24 and M34 produced the highest and the lowest leaf yield, respectively, during early and late dry seasons.

C24 produced the highest while M35 produced the lowest branch yield for the whole year, and over all yield varied from 743 to 2,750 g DW/plant (table 7). However, season-wise, for the early and late wet seasons, N14 and V1 were the highest, while P13 and M33 were the lowest, respectively. Provenance C24 produced highest branch both during the early and late dry seasons, while M34 and M35 produced low yields during early and late dry seasons.

Shoot yield for the whole year was the highest in C24 and the lowest in M34, varying from 1,839 to 5,903 g DW/plant over all provenances (table 8). Shoot yields of C24 were highest and those of M34 lowest during early and late dry seasons, respectively. Furthermore, during the early and late wet seasons, C24 and V1 produced the highest shoot yields while P13 and M33 produced the lowest.

For a guardrow system, the present data indicate C24, G14 and N14 are suitable for fodder production while for wood production C24, N14 and M38 were most suitable. In terms of dual purpose guardrow shrubs C24, G14 and N14 showed promise. With C24 and G14 produced higher fodder and wood during the dry season than they did during wet season, showing there is potential for selecting gliricidia provenances as fodder crop with strategic lopping when grown in the guardrow system. Furthermore, with 2 months lopping interval during the west season extending to 4 months during the dry season, the gliricidia could produce high yields of green leaves all the year around.

In general the present experiment showed that provenances C24, N14 and G14 were ranked first, second and third in that order (table 9) measured in terms of the 9 growth parameters (see table 2 to table 4) and 18 yield

Table 6. Leaf yield of *G. sepium* provenances during the wet and dry seasons in the guardrow system

Provenance code	Leaf yield				
	Wet season		Dry season		Whole year (1989)
	January	March	July	November	
	g DW/plant				
G13	694.88	282.95	316.27	657.44	1,951.54^{ef} [1)]
G14	564.44	934.31	662.88	746.52	2,908.15^{ab}
G15	498.78	707.59	259.16	504.81	1,970.34^{ef}
G17	568.68	380.00	579.25	864.93	2,392.86^{cde}
M33	426.40	128.19	156.35	389.12	1,100.06^{h}
M34	387.97	246.21	105.95	350.52	1,090.65^{h}
M35	460.45	277.03	350.65	426.21	1,514.34^{gh}
M38	717.33	363.03	444.50	554.68	2,079.54^{ef}
M39	659.08	878.41	341.09	584.99	2,463.57^{cd}
M40	553.22	301.44	265.80	641.94	1,762.40^{f}
V 1	569.93	907.93	347.59	465.58	2,291.03^{cde}
R12	787.89	408.56	371.13	610.94	2,178.52^{de}
P13	380.98	253.70	148.78	420.80	1,204.26^{h}
N14	878.62	635.12	508.91	651.11	2,673.76^{bc}
C24	1,086.35	473.16	709.88	883.78	3,153.17^{a}
I	416.60	392.39	339.61	584.26	1,732.86^{fg}
Mean ± SD	603.22 ± 194.48	473.13 ± 258.38	369.24 ± 175.67	583.60 ± 157.98	2,029.19 ± 617.73
SEM [2)]	–	–	–	–	138.65

[1)] Values in the same column with different superscripts differed ($p < 0.05$).
[2)] SEM = Standard error of the treatment means.

Table 7. Branch yield of *G. sepium* provenances during the wet and dry seasons in the guardrow system

Provenance code	Branch yield				
	Wet season		Dry season		Whole year (1989)
	January	March	July	November	
	g DW/plant				
G13	834.21	102.58	331.35	351.60	1,619.74^{bcd} [1)]
G14	486.54	286.68	676.19	447.51	1,896.92^{bc}
G15	443.33	190.26	242.09	222.54	1,098.22^{ef}
G17	550.86	131.43	321.88	499.22	1,503.39^{cd}
M33	452.69	44.05	151.82	174.70	823.26^{f}
M34	399.90	76.55	64.40	207.74	748.59^{f}
M35	336.62	69.10	177.31	160.30	743.33^{f}
M38	969.24	156.83	534.35	313.44	1,973.86^{b}
M39	656.63	188.85	292.34	337.99	1,475.81^{de}
M40	570.37	61.29	142.49	277.39	1,051.54^{f}
V1	585.46	540.14	347.01	410.52	1,883.13^{bc}
R12	779.30	124.05	333.73	370.14	1,607.22^{bcd}
P13	295.65	69.24	332.48	264.38	961.75^{f}
N14	1,147.38	236.21	657.97	482.69	2,524.25^{a}
C24	1,090.33	144.30	890.53	624.93	2,750.09^{a}
I	533.61	252.59	396.61	291.74	1,474.55^{de}
Mean ± SD	632.63 ± 261.01	167.13 ± 123.34	368.28 ± 221.31	339.80 ± 128.60	1,508.47 ± 600.79
SEM [2)]	–	–	–	–	129.56

[1)] Values in the same column with different superscripts differed ($p < 0.05$).
[2)] SEM = Standard error of the treatment means.

Table 8. Shoot (branch + leaf) yield of *G. sepium* provenances during the wet and dry seasons in the guardrow system

Provenance code	Shoot yield				
	Wet season		Dry season		Whole year (1989)
	January	March	July	November	
	g DW/plant				
G13	1,529.09	385.53	647.62	1,009.04	3,571.28[b] [1)]
G14	1,050.98	1,220.99	1,339.07	1,194.03	4,805.07[ab]
G15	842.11	897.85	501.25	727.35	3,068.56[b]
G17	1,119.54	511.43	901.13	1,364.15	3,896.25[b]
M33	879.09	172.24	308.17	563.82	1,923.32[c]
M34	787.87	322.76	170.35	558.26	1,839.24[c]
M35	797.07	346.13	527.96	586.51	2,257.67[bc]
M38	1,686.57	519.86	978.85	868.12	4,053.40[b]
M39	1,315.71	1,067.26	633.43	922.98	3,939.38[b]
M40	1,123.59	362.73	408.29	919.34	2,813.94[b]
V 1	1,155.39	1,448.07	694.60	876.10	4,174.16[ab]
R12	1,567.19	532.61	704.86	981.08	3,785.74[b]
R13	676.63	322.94	481.26	685.18	2,166.01[bc]
N14	2,026.00	871.33	1,166.88	1,133.80	5,198.01[a]
C24	2,176.68	617.46	1,600.41	1,508.71	5,903.26[a]
I	950.21	644.98	736.22	876.00	3,207.41[b]
Mean ± SD	1,230.23 ± 450.99	640.26 ± 363.69	737.52 ± 381.01	923.40 ± 276.15	3,537.67±1,178.88
SEM[2)]	–	–	–	–	892.10

[1)] Values in the same column with different superscripts differed ($p < 0.05$).
[2)] SEM = Standard error of the treatment means.

Table 9. The highest ranking order of the 27 growth and yields parameters in each provenance during the wet and dry seasons

Provenance code	Ranking order[1)]		
	1	2	3
G13	0	0	1
G14	4	8	3
G15	0	0	1
G17	3	5	3
M33	0	0	0
M34	0	0	0
M35	1	0	1
M38	1	1	3
M39	0	0	2
M40	0	1	1
V 1	2	1	1
R12	0	0	1
R13	0	0	0
N14	5	5	5
C24	11	5	3
I	0	1	2
n	27	27	27

[1)] Highest 3 ranking orders of the 16 provenances.

parameters (see table 5 to table 8). Sukanten et al. (1995a) found that N14, G14 and I were ranked first, second and third, respectively when grown as alley cropping system; while when grown as fence system, rankings were G14, N14 and I, respectively (Sukanten et al., 1995b), demonstrating the effect of different planting systems. However, the Bali local provenance (I) not promising as a guardrow system. Competition between the plants is probably an important factor since in the guardrow system row spacings 100 cm were compared with 50 cm in the alley cropping and 10 cm in the fence system. Ella et al. (1989) also found that the leucaena yield decreased as the plant row spacing reduced. An experiment in Bali, showed that the leaf yield of gliricidia provenances, when expressed per plant, was highest in guardrow system (100 cm spacing); but when expressed per 100 m of row the leaf yield was highest in fence system (10 cm spacing) (Nitis et al., 1991). An experiment in Ibadan (Nigeria), indicated that G14 and G17 were ranked first and second in total growth and leaf yield (Cobbina and Atta-Krah, 1992); experiments in Utchee Creek (Australia) and Sie Putih (Indonesia) showed that G14, G17, and N14 were ranked highest for leaf yield (Bray et al., 1993). Such discrepancies might be due to different managements, soil acidity (pH) and rainfall (R) between Ibadan (pH 6.2; R 320 mm), Utchee Creek (pH 5.0; R 3,500 mm), Sie Putih (pH 5.0; R 1,900 mm) and Bukit Bali (pH 7.8; R 1,000 mm).

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