Acid-Soil and Psyllid Tolerance of Interspecific Hybrids of Leucaena in Malaysia

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ABSTRACT : Seven hybrid lines of *Leucaena leucocephala* × *L. diversifolia* and two control lines of *L. leucocephala* were compared for their adaptation to acid-soils and tolerance to damage by the psyllid, *Heteropsyla cubana*, at four locations over two years in Peninsular Malaysia. Primary data on leaf composition and *in vitro* digestibility (nutrition variables) and secondary data on plant height, stem girth and psyllid damage (agronomy variables) were the measures of performance. Cluster solutions of the nine lines were different within locations, between locations and between years for nutrition and agronomy variables. Controls and hybrids did not cluster separately. Principal component scores of the nine lines gave rank orders which were different by location and by year. No performance trend could be detected between hybrids and controls. The conclusion is that nutritional and agronomic characteristics in Leucaena are independent, soil composition and weather did not consistently affect performance, and evidence is inconclusive as to the benefits of interspecific crossing with *L. diversifolia*.
(Key Words: Leucaena, Hybrids, Acid Soil, Psyllid Tolerance)

INTRODUCTION

In the tropics, the high growth and production potential of *Leucaena leucocephala* in basic soils is however not realised in acid soils of pH less than five (Sanchez and Salinas, 1981). The crop is also susceptible to attack by the psyllid, *Heteropsylla cubana*. However *Leucaena diversifolia* was found to have high acid-soil and psyllid tolerance in the llanos oxisol of Colombia (Hutton, 1981) and interspecific hybrids between *L. leucocephala* and *L. diversifolia* gave promising results in Brazil (Hutton, 1990). In 1988, a programme to screen and select acid-soil and psyllid tolerant hybrids of *L. leucocephala* line (2n=104), *L. diversifolia* line 25 (2n=52) and *L. diversifolia* line 31 (2n=104) was initiated by the Malaysian Agricultural Research and Development Institute. The programme was conducted at four locations exhibiting a range of soil pH.

The primary objective of the following study was to report on the agronomic performance and leaf nutritive value of the F4 and F5 hybrid generations in relation to the controls. Variation in the growth and fodder yield of 16 provenances of *Gliricidia sepium* (Sukanten et al., 1995) and of growth form, yielding ability and leaf digestibility of 28 provenences of *Gliricidia sepium* (Bray, 1994) have been reported. Following the observation of independence between the agronomy of rice and the nutritive value of rice straw (Vadiveloo, 1995), the present study was also intended to ascertain if a similar relationship existed between the agronomy and nutritive value of Leucaena.

MATERIALS AND METHODS

Agronomy

Data on height, stem girth at 50 cm and extent of psyllid damage (agronomy variables) of 2 control and 7 hybrid lines were assembled from Chen et al (1995) and Hutton and Chen (1993). Psyllid damage was rated on a 1-5 scale where 1 = no leaflet damage, 2 = some leaflet yellowing, 3 = 25% leaflet drop, 4 = 50 % leaflet drop and 5 = 75% leaflet drop with blackened petioles. Nodulated seedlings from these 9 lines had been raised in polybags in December 1993 (F4) and December 1994 (F5 generation) and each line transplanted in triplicate plots (25.0 m × 2.0 m) according to a completely randomised block design. In each plot, a minimum of 100 trees were planted in 2 rows, 0.5 m apart and with trees 1.0 m apart. Lines were planted in 4 sites, Serdang, Kuala Linggi, Jeram Pasu and Gajah Mati. The topography of the 4 sites was flat, with a slope range of 0-2° (Lim et al., 1997). At each site, fertilizer application per hectare was 100 kg triple superphosphate, 100 kg muriate of potash and some

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trace elements. Kuala Linggi received in addition 500 kg per hectare of dolomite. Soil from the above 4 sites was sampled at depths of 0-20 cm, 20-40 cm, 40-60 cm and 60 -80 cm and analysed for pH, soluble P and exchangeable Ca and Al.

Leaf composition and digestibility

Leaf rachis samples of the 9 lines from the four locations were harvested November 1994 (F4) and November 1995 (F5), oven-dried at 60℃ and ground in a grinding mill (1 mm sieve). The plants were therefore of 12 months age when harvested; the F4 and F5 leaf samples were harvested from the intact plant. Milled samples were analysed in triplicate for total ash (totash) by complete combustion in a muffle furnace (AOAC, 1984), neutral detergent fibre (NDF) and ash insoluble in neutral detergent solution (insol ash) by the method of Goering and Van Soest 1970), calcium by atomic absorption spectrophotometry and *in vitro* digestibility (nutrition variables). Digestibility (IVD) was estimated by incubating for 48 hr at 37℃ in cellulase Onozuka 3S; Yakult Biochemicals) followed by hydrolysis in neutral detergent solution (Bughrara and Sleper, 1986).

Statistical analysis

Univariate analysis of variance on the effects of location and year on leaf composition and IVD were estimated by the method of least squares to fit general linear models. A Type III estimable function was used in hypothesis testing.

Stepwise discriminant analysis was carried out to identify criterion nutrition variables within locations and within years. A significance level of 15% and a squared partial correlation of 0.85 were the selection criteria for entry into or removal from the discriminant model. Stepwise discriminant analysis of the agronomy variables was not carried out due to the lack of replication; only mean values were reported in Chen et al. (1995) and Hutton and Chen (1993).

Cluster analysis of the 9 lines within years and within locations was carried out using the criterion nutrition variables. Data were standardized (mean = 0, standard deviation = 1) and no outliers were trimmed. Clusters were formed by agglomerative hierarchical clustering and combined at each step by the method of complete linkage. A three-cluster solution of the data, representing a 33% reduction in the number of lines, was tabulated. Cluster analysis of the 9 lines was also carried out using all the agronomy variables as criterion variables. The cluster solutions from the two sets of variables were compared.

Principal component analysis of the nutrition and agronomy data was carried out to rank the lines, by location and by year, on the basis of their principal component scores.

Univariate and multivariate analyses were run on a SAS Version 6 (Statistical Analysis Systems Institute Inc, 1987) statistical package. The GLM procedure for unbalanced data was used in the analysis of variance.

RESULTS

Agronomy

Data on the pedigree and agronomic characteristics of the 9 lines were available from only three locations (table 1). The composition of soil in the four locations is shown in table 2. Kuala Linggi is characterised by high soil acidity, low exchangeable Ca and high exchangeable Al. Serdang soils exhibited a good pH-Ca-Al balance. Jeram

Table 1. Pedigree and agronomic characteristics of selected Leucaena lines in 1994

Line	Pedigree	Plant Height (cm)			Stem Girth (cm)			Psyllid Damage	
		Kuala Linggi	*Serdang*	*Gajah Mati*	*Kuala Linggi*	*Serdang*	*Gajah Mati*	*Serdang*	*Gajah Mati*
53-1-4	11×31	204	215	163	1.6	1.8	2.1	3.1	2.7
62-6-3	11×25	217	203	220	1.7	1.6	1.6	2.6	1.4
62-6-8	11×25	209	217	243	1.6	1.7	2.0	3.5	1.3
39-2-18	11×25	189	118	172	1.5	0.8	1.1	1.3	1.6
40-1-18	11×31	208	210	244	1.7	1.7	1.9	0.6	1.1
51-1-4	11×25	217	123	173	1.6	0.8	2.1	0.7	1.7
53-3-15	11×31	222	119	182	1.8	0.8	1.1	0.7	1.4
ML1		262	204	214	2.1	1.4	1.5	2.0	1.2
Cunningham		148	163	179	1.0	1.0	1.4	2.0	1.7

(Source : Chen et al., 1995; Hutton and Chen, 1993).

Table 2. Soil composition of the four locations

Location	Depth (cm)	pH	Soluble P (ppm)	Exchangeable Cations (meq/100 g)	
				Ca	*Al*
Kuala Linggi	0-20	3.5	22.2	0.62	6.2
	20-40	3.5	15.2	0.65	6.8
	40-60	3.2	9.9	0.94	9.3
	60-80	2.7	7.3	1.21	15.1
Serdang	0-20	4.6	26.3	0.62	1.3
	20-40	4.6	15.0	0.49	1.4
	40-80	4.6	9.0	0.34	1.5
Jeram Pasu	0-20	5.3	9.2	1.21	0.3
	20-40	4.6	5.2	0.64	1.3
	40-60	4.7	4.9	0.69	1.7
	60-80	4.6	5.1	0.80	1.7
Gajah Mati	0-20	5.0	14.0	1.54	0.1
	20-40	5.2	8.0	1.33	0.1
	40-60	5.0	4.0	0.63	1.1
	60-80	5.0	4.0	1.26	1.0

(Source : Chen et al., 1995; Hutton and Chen, 1993).

Pasu was characterised by high exchangeable Ca and low exchangeable Al. Gajah Mati has soil of low acidity, high exchangeable Ca and low exchangeable Al.

The prevailing weather conditions at the four locations in 1994 and 1995 are recorded in table 3. Between years, rainfall was higher in 1994 than 1995. But variation was considerable within years. Temperature and humidity showed little variation between years and locations.

Table 3. Total rainfall received (mm), temperature (℃) and relative humidity (% at 8.00 am) at the four locations

Location	Quarter	Total Rainfall		Temperature		Relative Humidity	
		1994	1995	1994	1995	1994	1995
Kuala Linggi	January-March	415	489	27	27	97	98
	April-June	770	414	28	29	97	97
	July-September	672	702	27	28	97	97
	October-December	679	548	27	27	97	96
Serdang	January-March	749	655	28	28	95	95
	April-June	676	913	28	28	96	95
	July-September	312	499	27	27	94	95
	October-December	584	733	28	27	96	95
Jeram Pasu	January-March	382	356	26	25	97	97
	April-June	599	578	28	28	95	95
	July-September	904	1028	27	28	95	94
	October-December	2504	1434	26	26	97	97
Gajah Mati	January-March	453	222	28	28	93	93
	April-June	520	473	28	29	96	95
	July-September	356	635	28	28	96	95
	October-December	321	461	27	27	94	95

(Source : Malaysian Meteorological Service, 1994, 1995).

Leaf composition and digestibility

The number of leaf samples available for analysis was unbalanced and hence the use of the GLM procedure. The effect of location and year on the IVD and composition of the nine lines are given in table 4. Within lines, differences in IVD and NDF between locations were

Table 4. Effect of location and year on the IVD (%), calcium content, NDF, total ash and insoluble ash (% in DM) of Leucaena lines

Parameter	Line	Location					Year		
		Kuala Linggi	*Serdang*	*Jeram Pasu*	*Gajah Mati*	*P >F*	*1994*	*1995*	*P >F*
IVD	53-1-4	79.1	69.4	58.2		***	70.0	64.3	ns
	62-6-3	74.1	67.6	62.2	70.6	**	69.1	67.4	ns
	62-6-8	75.8	73.5	57.9	73.8	***	64.1	71.5	ns
	39-2-18	72.0	68.0	64.0		ns	67.2	68.5	ns
	40-1-18	73.2	66.4	54.9	73.0	***	61.4	68.9	ns
	51-1-4	73.3	70.0	61.7		***	67.5	70.3	*
	53-3-15	77.2	69.2	65.0		*	67.2	70.6	ns
	ML1	71.8	69.6	49.9	76.9	ns	68.2	73.0	ns
	Cunningham	65.9	72.5	56.7	78.3	*	72.7	71.6	ns
Calcium	53-1-4	0.8	0.6	0.7		ns	0.9	0.6	ns
	62-6-3	1.1	0.5	0.7	1.1	***	0.8	0.8	ns
	62-6-8	0.7	0.6	0.8	1.0	**	0.9	0.7	**
	39-2-18	0.5	0.5	0.7		ns	0.4	0.5	*
	40-1-18	0.5	0.6	0.7	1.0	**	0.5	0.7	*
	51-1-4	0.6	0.5	0.8		ns	0.4	0.7	***
	53-3-15	0.4	0.6	0.7		**	0.4	0.7	**
	ML1	0.6	0.5	1.0	0.8	ns	0.4	0.8	**
	Cunningham	0.5	0.4	0.5	0.6	ns	0.3	0.5	ns
NDF	53-1-4	25.6	31.8	41.9		***	32.4	37.0	ns
	62-6-3	29.3	33.2	40.8	30.5	**	32.4	35.1	ns
	62-6-8	29.4	31.5	44.4	30.4	***	39.8	32.6	*
	39-2-18	33.3	33.0	37.6		ns	35.6	33.7	ns
	40-1-18	27.2	32.7	42.7	27.5	***	38.6	30.3	**
	51-1-4	31.2	31.4	40.7		**	31.0	33.6	ns
	53-3-15	26.6	31.6	37.6		**	32.9	31.5	ns
	ML1	26.2	32.8	49.4	24.8	*	32.6	28.8	ns
	Cunningham	25.1	30.4	46.5	30.3	**	29.4	32.6	ns
Total ash	53-1-4	5.0	4.0	5.5		ns	5.5	4.9	ns
	62-6-3	5.2	4.7	6.1	5.9	*	5.3	5.5	ns
	62-6-8	5.2	4.9	5.8	6.9	**	6.0	5.4	*
	39-2-18	4.9	5.7	6.3		**	5.5	5.6	ns
	40-1-18	4.4	5.4	5.1	5.0	*	5.3	5.1	ns
	51-1-4	4.7	5.0	6.0		***	4.9	5.2	*
	53-3-15	4.1	5.8	5.7		***	5.3	5.5	*
	ML1	4.5	5.4	6.4	6.8	ns	5.4	6.0	ns
	Cunningham	4.5	5.7	5.7	5.5	ns	5.7	5.4	ns
Insol ash	53-1-4	0.5	0.9	2.2		***	1.6	1.5	**
	62-6-3	1.7	1.8	1.7	1.4	ns	2.2	1.3	*
	62-6-8	0.7	0.8	2.2	1.0	***	2.2	0.8	***
	39-2-18	1.2	1.2	1.2		ns	1.8	1.0	*
	40-1-18	0.7	1.3	2.1	0.9	*	2.3	0.9	***
	51-1-4	0.6	1.1	1.5		ns	1.2	1.0	ns
	53-3-15	0.5	1.1	0.8		ns	2.1	0.6	***
	ML1	2.8	1.5	1.6	1.5	ns	1.7	1.6	ns
	Cunningham	1.7	1.4	2.0	0.8	ns	1.3	1.3	ns

ns = $p > 0.05$; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

generally significant but their differences between years were not significant ($p > 0.05$). For calcium, total ash and insoluble ash contents, however, there was no consistent effect of location or year.

Multivariate analysis

The criterion nutrition variables identified by stepwise discriminant analysis are given in table 5. For Gajah Mati, none of the variables satisfied the selection criteria for entry into the discriminant model; data from Gajah Mati were therefore excluded from further multivariate analyses.

The three-cluster solutions for year and location are given in table 5. For nutrition variables, control lines did not cluster separately from hybrids in both years and in all locations except Kuala Linggi (Cluster 3). In Jeram Pasu, ML1 clustered separately from Cunningham. There was no consistent grouping of hybrid lines by year or location. For agronomy variables, ML1 and Cunningham clustered separately in all locations. There was some evidence of agronomic similarity between lines 62-6-3 and 62-6-8 as they were to be found in the same clusters.

The variance explained by the first principal component on the nutrition and agronomy variables ranged from 45.4% to 100%. Lines were ranked from 1-9 on the basis of their scores on the first principal component, a rank order of 1 given to the highest negative score and a rank order of 9 for the highest positive score. The results given in table 6 show that the rank order of the lines was different by location and year for both nutrition and agronomy variables.

DISCUSSION

The common criterion nutrition variables discriminating lines within locations and years were total ash and insoluble ash. In a study on varietal differences in rice

Table 5. Variables and three-cluster solutions of Leucaena lines by year and location

Year/ Location	Variable				Cluster		
	Ca	*Totash*	*Inash*	*NDF*	*1*	*2*	*3*
1994	×	×		×	53-3-15 ML1 53-1-4 62-6-3 39-2-18 40-1-18	51-1-4 Cunningham	62-6-8
1995	×	×	×	×	62-6-8 53-3-15 39-2-18 Cunningham 40-1-18 51-1-4 62-6-3	ML1	53-1-4
Kuala Linggi		×	×		53-1-4 62-6-8 39-2-18 62-6-3	40-1-18 51-1-4 53-3-15	ML1 Cunningham
Serdang		×			40-1-18 ML1 39-2-18 Cunningham 53-3-15	62-6-8 51-1-4 62-6-3	53-1-4
Jeram Pasu	×	×	×		62-6-3 51-1-4 39-2-18 53-3-15	53-1-4 40-1-18 62-6-8 Cunningham	ML1

Table 5. (Cont.)

Year/ Location	Variable			Cluster		
	Height	*Girth*	*Psyllid*	*1*	*2*	*3*
Kuala Linggi	×	×		53-1-4 62-6-8 40-1-18 62-6-3 51-1-4 53-3-15 39-2-18	ML1	Cunningham
Serdang	×	×		39-2-18 53-3-15 51-1-4	62-6-8 40-1-18 53-1-4 62-6-3 ML1	Cunningham
Gajah Mati	×	×		62-6-8 40-1-18 62-6-3 ML1	53-1-4 51-1-4	39-2-18 53-3-15 Cunningham
Serdang			×	51-1-4 53-3-15 40-1-18 39-2-18	ML1 Cunningham 62-6-3	53-1-4 62-6-8
Gajah Mati			×	62-6-3 53-3-15 40-1-18 ML1 62-6-8	51-1-4 Cunningham 39-2-18	53-1-4

straw, it was also found that these components were the more important variables contributing to differences in straw varieties (Vadiveloo, 1992, 1995).

Within the locations Kuala Linggi and Serdang, the cluster solutions and the rank order of lines based on nutrition variables and agronomy variables were different (table 5 and table 6). This suggested that the two sets of variables were independent. Similar observations have

Table 6. Rank order of lines based on the scores on the first principal component by location and year for nutrition and agronomy variables

Line	Nutrition					Height & Girth			Psyllid	
	Kuala Linggi	*Serdang*	*Jeram Pasu*	*1994*	*1995*	*Kuala Linggi*	*Serdang*	*Gajah Mati*	*Serdang*	*Gajah Mati*
53-1-4	8	1	3	8	1	3	9	4	8	9
62-6-3	6	2	5	6	5	7	6	7	7	4
62-6-8	9	3	4	9	6	4	8	9	9	3
39-2-18	5	7	8	5	3	2	1	1	4	6
40-1-18	4	5	1	7	7	6	7	8	1	1
51-1-4	3	4	7	1	4	5	3	6	2	7
53-3-15	7	9	6	3	8	8	2	2	3	5
ML1	1	6	9	4	9	9	5	5	5	2
Cunningham	2	8	2	2	2	1	4	3	6	8

been reported between the agronomy of cereals and the nutritive value of their straws (Capper, 1988; Vadiveloo, 1995 and Colucci et al., 1992) and between the growth form and yielding ability of 28 provenances of *Gliricidia sepium* and the digestibility of their leaves (Bray, 1994).

Within nutrition and agronomy variables, there was no consistent grouping of lines by year or by location suggesting that soil and rainfall differences did not consistently affect these characteristics. This is in agreement with findings of seasonal effects on the growth and fodder yield of 16 provenances of *Gliricidia sepium* (Sukanten et al., 1995) but in contrast to the findings on the effect of location and season on the nutritive value of rice straw varieties where consistent effects were obtained (Vadiveloo and Phang, 1996).

Control and hybrid lines did not cluster separately when based on nutrition or agronomy variables (table 5) suggesting that the inter-specific crossing of *L. leucocephala* and *L. diversifolia* had not generally altered nutritional or agronomic characteristics.

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