YIELD AND DIGESTIBILITY OF FORAGES IN EAST INDONESIA
I. LEGUMES

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Summary

This study was undertaken at Gowa, South Sulawesi, Indonesia as part of a larger forage genetic resource evaluation project. The experimental program consisted of a field experiment where grasses and legume species were grown in monocultures and the yield, N content and rumen bag digestibility using goats were measured. The field experiment was conducted from December 1985 to October 1986. Eight species of legumes (*Desmodium heterophyllum* cv. Johnstone, *Desmodium triflorum* from Gowa, South Sulawesi, *Arachis* sp. from Maiwa, South Sulawesi, *Clitoria ternatea* CPI 50973, *Macroptilium atropurpureum* cv. Siratro, *Neonotonia wightii* cv. Tinaroo, *Centrosema pubescens* CPI 58575, *Centrosema plumeri* CPI 58568) were grown as monocultures. After establishment all plants were cut to a uniform height of 5 cm, and subsequent cuts were made on regrowth after 14, 28, 42, and 56 days (cycle 1). Cycle 2 commenced towards the end of the wet season and continued for 157 days into the dry season. The highest yielding legumes were *C. ternatea* in the wet season and *Arachis* sp. in the dry season. The mean rumen bag dry matter digestibility (RBDMD) of legumes of 67.6% for leaf material (averaged over all cycles and ages) was 7.6% higher than for stem material. The RBDMD of *Arachis* was significantly higher than all other species. The RBDMD of all legumes declined with age. Calculation of yield of digestible DM (yield × RBDMD) showed that *Arachis* sp. was the best legume. The combination of plant "quality" with yield measures is a valuable adjunct to routine agronomic survey procedures in plant evaluation programs. *Arachis* sp. appears to offer considerable promise and should be more widely evaluated.
(Key Words: Legumes, DM Yield, Rumen Bag Digestibility)

Introduction

When evaluating forages for their potential to support high levels of animal production, Leng (1985) has identified a number of considerations which need to be taken into account. These include interactive and interdependent factors such as voluntary intake, digestibility, extent of ruminal digestion of the fibrous components, efficiency of microbial growth, the capacity of constituent protein and starch to determine rumen fermentation and digestion in the intestines. Substantial variation in intake occurs between species, and the voluntary intake of legume is usually higher than that of grasses, and leaf higher than that of stem (Minson, 1982). The lower intake of stem than leaf is almost certainly as much associated with the different anatomical arrangement of fibre in these tissues as with the difference in the total amount of indigestible cell wall (Wilson, 1985). The fibre content of forages increases with age of the plant. Coincident with this increase there is a reduction in the proportion of protein and non-structural carbohydrates of the cell contents which results in a decrease in the nutritive value of the feed. As a consequence, digestibility and intake by animals are also reduced (Norton, 1982). In the study reported here eight herbaceous legumes were planted in monoculture plots and cut after varying periods in both the wet and dry seasons. Their yield over time and changes in the nutritive value for animals were assessed.

Materials and Methods

General details of site

The experimental site was located at the BPT (Balai Penelitian Ternak) experiment station at Gowa, South Sulawesi Indonesia (latitude 5°S; longitude 119°E) and the study reported here was part of a larger genetic resource evaluation project.

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Received October 20, 1993
Accepted March 17, 1994

Initially a large range of native and introduced grass and herbaceous legume accessions was grown in a nursery and assessed in regard to persistence, dry matter and seed yield. Eight of the most promising herbaceous legumes were subsequently planted in small monoculture plots to allow further evaluation. They were cut after varying periods in both the wet and dry season to assess their yield over time and to obtain material of varying ages for nutritive value assessment. The soil has been described by McLeod (1984) as a well drained, highly permeable, silty clay loam with pH 6. (USDA classification: Typic Ustifluvent). The mean annual rainfall is excess of 2,000 mm, most of which falls during the period November to April. Mean monthly temperature is relatively constant (mean 29℃): however, the mean daily temperature can be highly variable and ranges from 19.5℃ to 35.5℃ (Meteorological and Geophysical Organisation, Ujung Pandang, 1984).

Management of plots

The land was ploughed, harrowed and hoed and then weeded weekly for one month to prevent the re-establishment of unwanted plants. The 8 legumes listed in table 1 were sown in monoculture in plots 2 m × 5 m with 1m between plots.

TABLE 1. SPECIES SOWN TO ASSESS YIELD AND NUTRITIVE VALUE

Species name	Cultivars	Abbreviation*
Desmodium heterophylium	cv. Johnstone	D.h.
Desmodium triflorum	ex. Gowa	D.t.
Arachis sp.	ex. Maiwa**	A.sp.
Clitoria ternatea	CPI 50973	C.t.
Macroptilium atropurpureum	cv. Siratro	M.a.
Neonotonia wightii	cv. Tinaroo	N.w.
Centrosema pubescens	CPI 58575	C.pu.
Centrosema plumieri	CPI 58568	C.pl.

* Notation used in subsequent figures.
** Probably identical to *A. glabrata* CPI 12121.

The species were allocated at random within each of the three replications. Plants were established in a 0.3 m × 0.3 m grid pattern from seed except for *D. heterophyllum*, *D. triflorum* and *Arachis* sp. which were planted as cuttings. After establishment, fertiliser was applied at a rate of 200 kg/ha triple superphosphate. Plots were watered twice daily until the onset of the wet season. Weeding was performed once per month by hand during this period. All species were established satisfactorily by December and a uniformity cut was made on December 16, 1985. Cutting height was 5 cm above ground level for all species.

After the uniformity cut, quadrats (0.75 m^2) were cut from predetermined areas (sub-plots) of the plot after 14, 28, 42 and 56 days of regrowth (cycle 0). Since the wet season was prolonged (figure 1) the plots were all cut to 5 cm following the 56 day sampling (11/2/86) and the 14, 28, 42, and 56 day sampling process was repeated (cycle 1). The dry season regrowth (cycle 2) was 157 days and consisted of regrowth from the 42 day harvest plots in cycle 1 (25/3/86) through to 30/8/86. The timing for the harvests in cycles 1 and 2 are shown in relation to the rainfall in figure 1.

Sample processing and statistical analysis

After harvesting, the few weeds present were removed from the sown species and discarded. The sown species were then separated into leaf and stem fractions. Samples were dried in an oven for 48 hours at 65℃, weighed and then ground in a mill to pass through a 2 mm screen. Following grinding, rumen bag dry matter digestibility (Bulo et al., 1992) and total nitrogen were determined, and the amount of digestible dry matter was calculated.

Dry matter yields

In the original design there were two short term regrowth cycles (0, 1) the aim being to ensure that at least one was in the wet season. These were followed by a dry season cycle (2) the start of which was estimated from what appeared to be the current weather pattern. With the unusually long wet season (figure 1) there were two complete wet season cycles and the dry season cycle only commenced after the 42 day cut in cycle 1. The samples from all the cycles were analysed as described above but as the results from cycles 0 and 1 were essentially the same the presentation has been restricted to the second wet cycle (1) and the dry cycle (2) (figrue 1). For cycle 1 these were analysed as a split plot with replications as blocks, species as main plots and the four regrowth periods as sub-plots. Cycle 2 was analysed in the same way without regrowth periods.

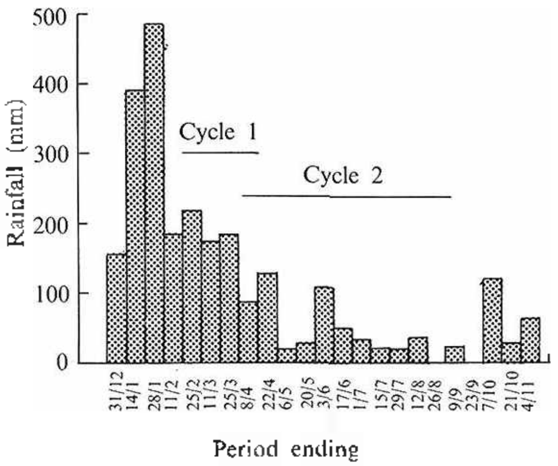


Figure 1. Rainfall (mm) presented in two week periods and the timing for cyc e 1 and 2.

Rumen bag digestibility

Rumen bag digestibility was determined using three goats following the technique described by Bulo et al. (1992). In brief, this technique involved the use of dacron bags (7 × 14 cm in size; 44 micron) with an effective surface area of approximately 150 cm^2; plant material dried and ground to pass through a 2 mm sieve; a sample size per bag of 1-3 g; six bags per goat; and an incubation time of 48 hours. Each of the two sets of analysis consituted a latin square design with the three goats (replications) as rows (goats were randomly allocated to rows) and time (three time periods when the rumen bag work was carried out) as columns. The aim being to remove both animal variability and variation in the time of analysis. The three cycles were allocated to the nine cells of each square where the first row was assigned randomly. Within each of the nine cells a cycle was analysed. Each cycle contained both leaf and stem fraction of 8 species. The order of these was assigned randomly and there were six bags per goat. Standard samples of *Macroptilium atropurpureum* were included in each run to monitor variability.

The statistical analysis of the data from the latin square design was carried out using the GENSTAT computer program. Cutting periods were analysed only within cycles, since the length of the periods varied with cycles and no comparisons were possible.

Digestible dry matter

Digestible dry matter was calculated from dry matter yields and rumen bag digestibility. Statistical analysis followed the dry matter yield analysis.

Total nitrogen

Total N (%) was obtained by the autoanalyzer method of Thomas et al. (1967) after digestion in H_2SO_4.

Results

Rainfall

Actual rainfall is presented per regrowth period for all cycles in figure 1. Rainfall was initially high during cycle 1. In cycle 2, rain was recorded early but this declined over the regrowth period.

Dry matter yield

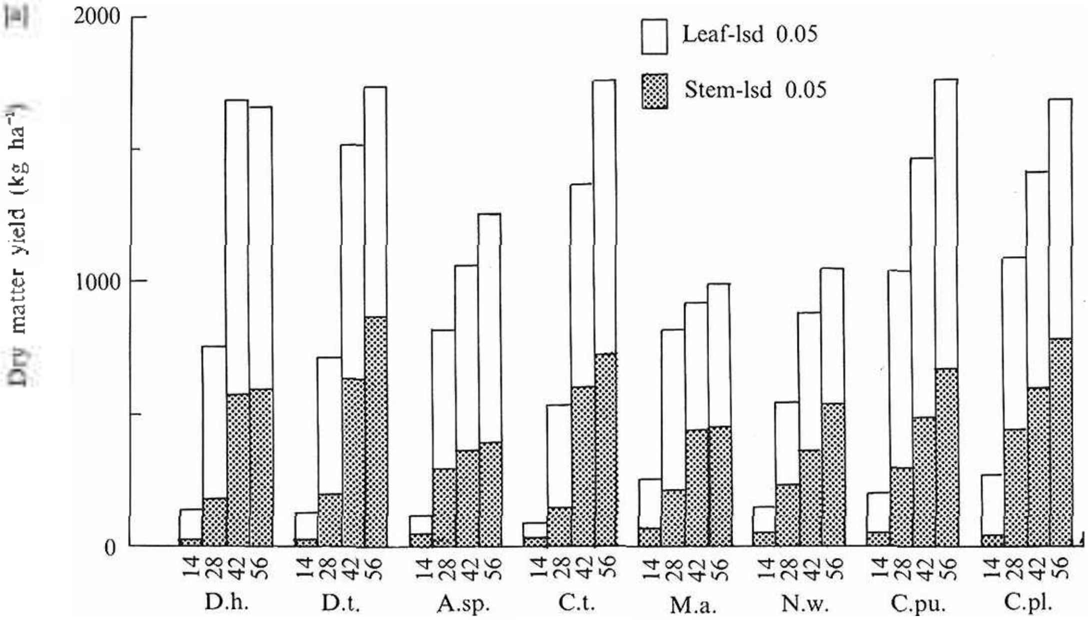
Cycle 1

Total yields increased throughout the 56 day growing cycle in all legumes except D. *heterophyllum*. Regrowth in the first 14 days was fastest in *C. plumieri* and *M. atropurpureum* and after the 56 day regrowth period yields were highest in *C. pubescens, C. ternata, D. triflorum, C. plumieri* and *D. heterophyllum* and lowest in *M. atropurpureum* and *N. wightii* (figure 2a). Leaf yields were higher than stem yields in all species at all harvests (figure 2a) for *N. wightii* at 56 days. The percentage of leaf on legumes in cycle 1 ranged from 52% in *M. atropurpureum* (42 days) and *C. plumieri* (56 days) to 85% in *D. heterophyllum* at 14 days (table 2).

Cycle 2

Cycle 2 extended for 157 days, from March 25 to August 30, 1986. The total rainfall in this period was 540 mm with dry periods recorded in May, July and August (figure 1). The total DM yield ranged from 1,710 kg/ha in *Arachis* sp. to a low of 580 kg/ha in *D. heterophyllum* (figure 2b). The ranking of species in this regrowth cycle was different from that in Cycle 1. The total DM yield of *Arachis* sp. was significantly higher ($p < 0.05$) than *M. atropurpureum, D. triflorum, C.*

ternatea and *D. heterophyllum*. The yields of *C. plumieri*, *N. wightii* and *C. pubescens* were intermediate between these and the lower yielding group. There were marked differences in the leafiness of the legumes values being greater than 50% in *Arachis* sp., *C. pubescens* and *C. plumieri* and a low of only 23% in *D. triflorum* (table 2).



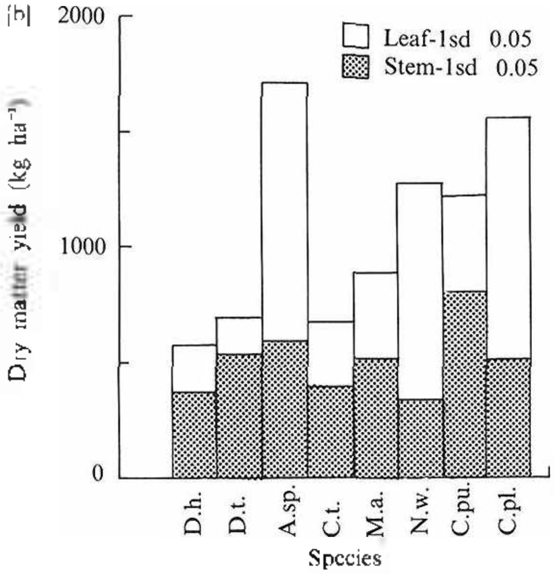


Figure 2. Dry matter yield (kg / ha) of leaf and stem components of legumes in cycle 1 and 2. The numbers on the abcissa of figure 2a show the regrowth periods in days. cycle 2 regrowth period in figure 2b was 157 days.

Rumen bag dry matter digestibility (RBDMD)
Cycle 1

After 14 days of regrowth in cycle 1 there were significant differences ($p < 0.05$) in the RBDMD between species and between leaf and stem components (table 3). The highest RBDMD of 78.5% was recorded in *Arachis* sp. leaf (table 3) and the lowest of 66.9% in *D. heterophyllum*. The ranking of the species in terms of RBDMD was *Arachis* sp. > *N. wightii* > *D. triflorum* = *C. ternatea* = *M. atropurpureum* = *C. pubescens* > *C. plumieri* = *D. heterophyllum*. The RBDMD of stem material at 14 days was lower than the leaf in all species. The greatest difference was in *N. wightii* where the stem RBDMD was 15.1% lower than in the leaf. By contrast the stem of *Arachis* sp. was only 3.4% less digestible than the leaf (table 3). There was a decline in the RBDMD of both leaf and stem with age in all species and this ranged from -0.13% day^{-1} in the leaf of *D. heterophyllum* and *C. plumieri* to -0.24% day^{-1} in the leaf of *N. wightii*. Despite these different rates of decline *Arachis* sp. had the highest leaf RBDMD after

TABLE 2. LEAF PERCENTAGE IN LEGUMES HARVESTED IN CYCLE 1 AND 2.

Species	Cycle 1				Cycle 2
	Regrowth time (days)				
	14	28	42	56	157
	(% leaf)				
D. heterophyllum	85	77	67	64	40
D. triflorum	83	73	60	52	23
Arachis sp.	62	64	66	71	65
C. ternatea	72	73	57	58	42
M. atropurpureum	76	74	52	55	42
N. wightii	67	58	58	50	49
C. pubescens	77	71	67	62	60
C. plumieri	84	60	58	52	59

TABLE 3. RUMEN BAG DRY MATTER DIGESTIBILITY OF LEGUME LEAF AND STEM IN CYCLE 1 AND 2 AND DECLINE BETWEEN 14 AND 56 DAYS IN CYCLE 1

Species	Cycle 1						Cycle 2	
	14 d RBDMD (%)		56 d RBDMD (%)		14-56 d decline (% day^{-1})		157 d RBDMD (%)	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
D. heterophyllum	66.9	61.4	61.5	56.3	0.13	0.12	62.4	55.1
D. triflorum	71.3	60.7	62.9	53.7	0.20	0.17	64.0	56.6
Arachis sp.	78.5	75.1	71.8	69.0	0.16	0.14	77.0	68.3
C. ternatea	70.5	63.6	62.9	53.5	0.18	0.24	69.1	54.4
M. atropurpureum	70.4	61.2	62.0	56.6	0.20	0.11	63.7	60.7
N. wightii	75.4	60.3	65.4	56.8	0.24	0.09	65.7	61.6
C. pubescens	70.2	62.9	62.7	57.0	0.18	0.14	61.7	55.0
C. plumieri	67.4	61.1	62.0	54.7	0.13	0.16	65.9	53.1
lsd ($p = 0.05$)		2.9					2.3	

56 days regrowth and *D. heterophyllum* and *C. pubescens* the lowest.

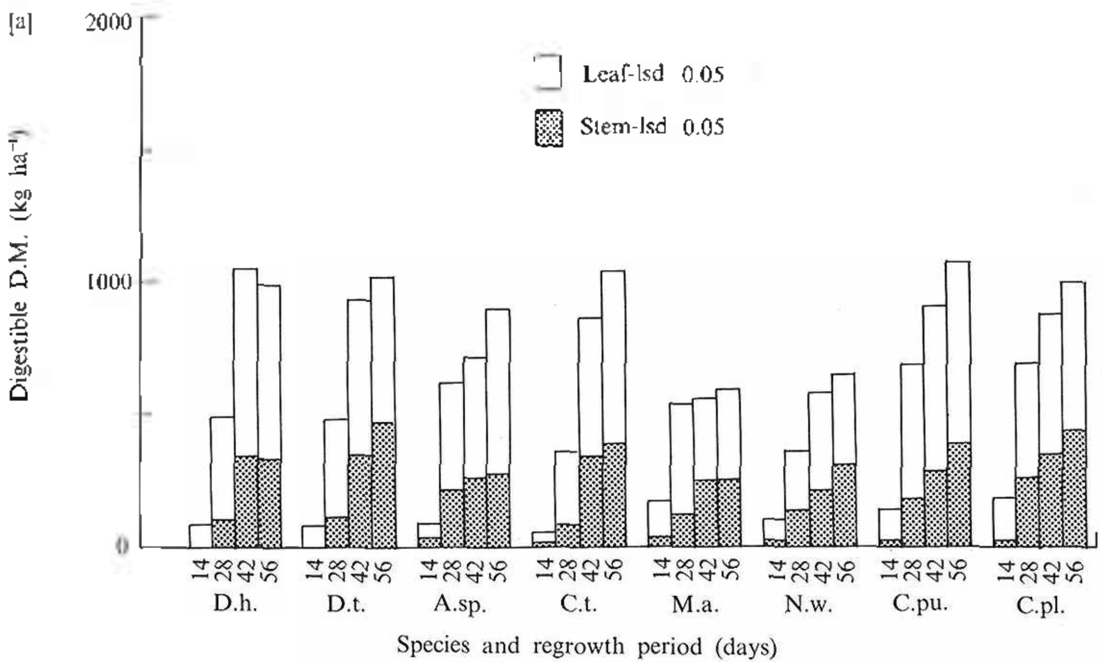
The calculated Rumen Bag DMD of the combined leaf and stem is shown in table 4. The rate of decline was lowest in *Arachis* sp. (0.15% day^{-1}) and highest in *D. triflorum* (0.33% day^{-1}).

Cycle 2

At the harvest taken after 157 days regrowth into the dry season the ranking of the species in terms of leaf and stem RBDMD was similar to that in cycle 1 (table 3). Highest leaf RBDMD (77.0%) was recorded in *Arachis* sp. and the lowest (61.7%) in *C. pubescens*. As in cycle 1, stem RBDMD was always lower than leaf in each species. Highest stem RBDMD (68.3%) was recorded in *Arachis* sp. and the lowest (53.1%) in *C. plumieri*. As in cycle 1 there were marked differences between species in the RBDMD of the whole plant (table 4). *Arachis* sp. again had the highest RBDMD.

Yield of digestible dry matter of legumes

In terms of animal production from a given area of land, the important parameters are not just the DMD per unit weight but the total amount of digestible dry matter potentially available. Consequently, the yield of digestible dry matter (subsequently referred to as DDM) in legumes has been calculated using leaf and stem



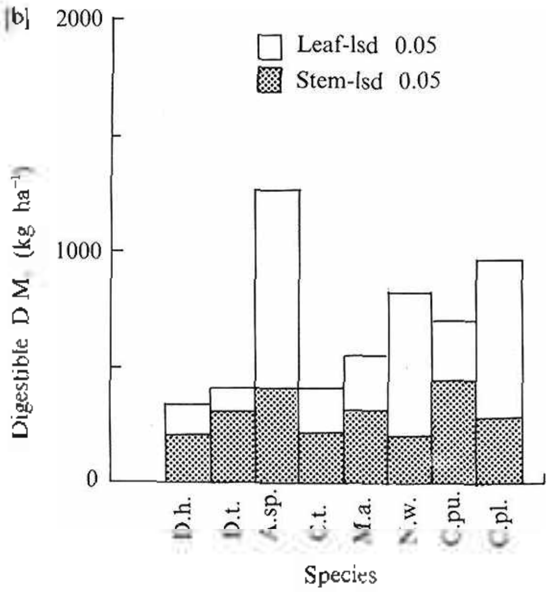


Figure 3. Yield of digestible dry matter (kg / ha) of leaf and stem components of legumes in cycle 1 and 2. The numbers on the abscissa of figure 3a show the regrowth periods of in days. The regrowth period for cycle 2 was 157 days.

yields and percentage DMD values and the results are presented in figure 3.

Cycle 1

In general, the ranking in cycle 1 of DDM (figure 3a) was similar for all species to the ranking of total DM yield (figure 2a). However, the DDM yield in *Arachis* sp. was ranked slightly higher than yield *per se* because of high DMD in both the leaf and stem fractions. Similarly, DDM yield in *C. pubescens* and *C. plumieri* was slightly lower than yield ranking because of changes in the leaf % throughout the cycle. In *M. atropurpureum* and *N. wightii* the DDM yield was lower, because of lower DM leaf production.

Cycle 2

At this time the highest leaf DDM yield was recorded in *Arachis* sp. (860 kg/ha) although this yield was not significantly higher than that in *C. plumieri* and *N. wightii*. The leaf DDM yield of the remaining species were not significantly different from each other. The lowest yield (100 kg/ha) was measured in *D. triflorum*.

The trend in DDM yields for the whole plant was similar to that of the leaf DDM yields. The DDM yield of 1,270 kg/ha in *Arachis* sp. was significantly higher than all the others except for *C. plumieri*. The DDM yield of *N. wightii* and *C. pubescens* were intermediate and *M. atropurpureum*, *C. ternatea*, *D. triflorum* and *D. heterophyllum* were in the lowest yielding group.

TABLE 4. CALCULATED RUMEN BAG DRY MATTER DIGESTIBILITY OF THE COMBINED LEAF AND STEM FRACTIONS OF LEGUMES IN CYCLE 1 AND 2 AND THE DECLINE BETWEEN 14 AND 56 DAYS IN CYCLE 1

Species	Cycle 1			Cycle 2
	14 d RBDMD (%)	56 d RBDMD (%)	14-56 d decline (day^{-1})	157 d RBDMD (%)
D. heterophyllum	66.2	59.6	0.17	58.0
D. triflorum	69.5	55.8	0.33	58.3
Arachis sp.	77.2	71.0	0.15	74.0
C. ternatea	68.6	59.0	0.23	60.5
M. atropurpureum	68.2	59.5	0.21	62.0
N. wightii	70.4	61.0	0.23	63.3
C. pubescens	68.5	60.4	0.20	59.0
C. plumieri	66.4	58.5	0.19	60.7
lsd (p = 0.05)		3.0		2.8

Nitrogen concentration in leaf and stem fractions of legumes

Because of the small amounts of plant material available at some harvests and the necessity to repeat some rumen bag analysis plant samples were not available for N analysis in all harvests. Consequently no statistical analysis was undertaken on these data. The leaf N concentration of the legumes analysed all exceeded 4.0% N at 14 days and declined in all species between 14 and 56 days in cycle 1 (table 5). The N concentration in stem material was always lower than leaf and only exceeded 2.5% N in *C. plumieri* at 14 days. There was a markedly lower leaf and stem N concentration in cycle 2 compared with cycle 1. After the 157 days regrowth period leaf N had declined to between 1.7 and 2.7% and stem N to between 1.1 and 1.8%N (table 5).

TABLE 5. NITROGEN CONCENTRATION IN LEAF AND STEM FRACTIONS OF LEGUMES IN CYCLE 1 AND 2

Species	Cycle 1				Cycle 2	
	14 d		56 d		157 d	
	Leaf	Stem	Leaf	Stem	Leaf	Stem
			(% N)			
D. heterophyllum	4.5	2.1	3.7	2.1	2.2	1.3
D. triflorum	4.0		3.1	2.1	2.1	1.7
Arachis sp.	—	—	3.0	2.0	2.1	1.1
C. ternatea	—	2.0	3.6	1.2	2.2	1.6
M. atropurpureum	4.2	2.3	3.7	2.0	2.4	1.3
N. wightii	4.0	2.2	3.7	2.0	1.7	1.8
C. pubescens	4.8	2.0	4.1	2.0	2.7	1.4
C. plumieri	4.3	3.0	3.8	2.0	2.6	1.4

—: insufficient sample.

Discussion

Dry matter yield

Whilst comprehensive forage evaluation studies have been carried out in Malaysia and Thailand, no such studies have been reported from Indonesia prior to the present study. In the wet season *C. ternatea* was in the top producing group and not significantly different in DM production from *D. heterophyllum*, *D. triflorum* and *C. pubescens*, while in the dry season *C. ternatea* was amongst the poorest producers. Humphreys, (1978) and Whiteman, (1980) have stressed the importance of the ability of forage species to produce dry matter in both the wet and dry season. Of the species evaluated in this study, *Arachis* sp. fulfilled this criterion of selection best. There were marked differences in the leaf % among species, and between regrowth times and regrowth cycles. When this is considered the ranking of leaf yield changes from total yield in the legumes. Among the legumes *D. heterophyllum* and *C. pubescens* produced the highest leaf yield in the wet season and *Arachis* sp. remained the highest yielder in the dry season.

Dry matter digestibility

The DM production of leaf and stem are unsatisfactory selection criteria on their own. The digestibility of the dry matter must also be taken into account. Although it is not possible to directly compare absolute digestibility data between experments it is possible to compare rankings. The range in RBDMD for the whole plant of legumes found in this experiment was from 55.8% to 77.2% (table 4) compared with the range of 54 to 69% reported in a larger number of legumes by Minson (1976) however this latter study did not include *Arachis*. The RBDMD for the whole plant of *Arachis* sp. was found to be significantly higher than all other species but, as for yield, no information is available from other studies for comparison. The mean of 64.5% RBDMD for leaf material averaged over all cycles and ages is 5.0 % higher than in stem material. Laredo and Minson (1973) and Hacker and Minson (1981) also reported higher digestibility of leaf material. The magnitude of the decline in whole plant RBDMD with age recorded in this study is similar to that reported by Reid et al. (1973) and is due to a greater proportion of stem material and older leaves. Hacker and Minson (1981) reported a greater decline in the digestibility of stem with age than in leaf material. The results from this study shows this to differ between species. *Arachis* sp. is the only legume evaluated which has a digestibility in excess of the 65% suggested as suitable by Leng (1985).

Yield of digestible DM

One way of integrating the effects of yield and DMD is to calculate the yield of DDM. A deficiency of this procedure is that it does not have a cut-off percentage of DMD below which the material is considered unacceptable. No satisfactory cut-off figure could be ascertained from the literature. If the value of 65% as suggested by Leng (1985) is adopted, then *Arachis* sp. would be the only species of acceptable quality. Because of the large differences in yield recorded between species in this study and the comparatively smaller differences in RBDMD, dry matter yield variations dominate the calculation of DDM yield and at any particular time there were only a few cases where the ranking of the species changed. On this basis *Arachis* sp. was the most successful legume, being particularly outstanding when regrown into the dry season (figure 3b).

Conclusions

Nitrogen data showed that all legumes had concentrations in excess of the 1.09% (6% crude protein) considered as minimal for proper rumen function. Of the species studied *Arachis* would appear to be the best legume in terms of DDM production throughout the year, and its position is further enhanced when the proportions of leaf an stem are considered. Evaluation of this species under grazing should be undertaken over a range of soil and climatic conditions.

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