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# **Integration of Ruminants into Plantation Systems in Southeast Asia**

**Proceedings of a workshop at Lake Toba,  
North Sumatra, Indonesia  
9–13 September 1994**

***Editors: B.F. Mullen and H.M. Shelton***

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## Executive Summary

THE DEMAND for beef and sheep meat in the Southeast Asian region is increasing steadily as populations grow and living standards improve. Countries within the region are not self-sufficient however, and importation of livestock and livestock products is increasing. Farm-gate prices for livestock are also increasing and there is great interest in low cost feeding systems such as pastures.

The potential for integration of ruminants into rubber, oil palm and coconut plantations is high, and at present the plantation area is under-utilised. The benefits from integration include diversified income, improved plantation crop yield and improved and environmentally sound weed control. Successful projects have been established in Malaysia and Indonesia to promote sheep integration under rubber. In Indonesia, a limited area of the coconut understorey has been utilised for ruminant production for many years, however animal production from the native pastures is commonly poor.

Through the work of ACIAR 9113 and preceding 8650 projects, our understanding of plant growth responses to shading, and forage species and grazing management systems applicable to ruminant production under plantation crops has greatly increased. The following is a brief summary of the results of this work.

### Forage species

Early attempts at ruminant integration into plantations established the need for improved pasture species and better management of plantations and ruminants. Strong grass swards were required to give sustainability of production and legumes were required to give high nutritive quality. Short statured grasses were found to be suited to grazed systems for both sheep under rubber and cattle under coconuts. Species suitable for cut-and-carry feeding systems were not necessarily suited to grazed production systems.

It was found that if initial establishment of associated legumes was poor, or early management did not maintain legume content, it was very difficult to rehabilitate the pasture to acceptable legume content. Several researchers reported difficulty maintaining herbaceous legumes with strongly growing grass species. The solution to this problem may be to use tree legumes.

For smallholders, vegetative propagation of species is recommended, especially for coconut plantations. Larger plantation owners are able to purchase seed from local or overseas sources. Appropriate pasture establishment methods are required that are suited to the range of plantation farming systems.

*Stenotaphrum secundatum*, *Brachiaria humidicola*, and *Arachis* species were the most successful prostrate herbaceous species for coconut plantations in Indonesia. *Paspalum malacophyllum* and *Calliandra calothyrsus* were productive species for use in cut-and-carry feeding systems. *Brachiaria humidicola*, *Paspalum notatum* and *Stylosanthes guianensis* CIAT 184 were the best species for rubber in Malaysia.

### The shade environment

The ability of regularly defoliated pasture grasses to partition resources into the development of new tillers was found to be an important persistence mechanism. Residual leaf area was found to be of lesser importance than the ability to rapidly regenerate leaf.

The improved nitrogen environment under shade was found to be related to increased organic matter breakdown due to improved moisture in the litter layer and improved activity of soil fauna. The light use efficiency of pastures under shade varied with species and environmental factors such as nitrogen and moisture status.

### **Animal and plantation management**

In Malaysia, reservations were expressed regarding the sustainability of improved forages for sheep production under conventional rubber planting systems. Competition from vigorous grasses reduced rubber growth and forage production levels under mature rubber was inadequate. There was strong evidence for a change to hedgerow planting systems for sustainable integrated production with livestock or horticultural crops. The hedgerow rubber system offered sustainability of sheep integration with minimal loss of rubber production. Computer modelling techniques enabled the evaluation of various hedgerow configurations with respect to the productivity of rubber, understorey forages and sheep.

Problems were experienced with the grazing management of *B. humidicola*. A practical grazing system was required which controlled growth and palatability of the grass, maintained legume content and kept endoparasite levels under control. A two month rotation may be required to achieve parasite control. Endoparasites are an increasing problem for susceptible sheep breeds in Southeast Asia. Parasites are developing resistance within sheep populations to the various chemical control groups. More resistant sheep breeds are being identified.

Energy as well as protein was limiting nutrition of sheep under rubber. Supplementation strategies were described.

In Indonesia, cattle integration into coconut plantations was found to increase copra yields where suitable pasture species were established to suppress weed growth. Careful grazing management was less crucial where highly robust and stable grass swards such as *Stenotaphrum secundatum* were established. However, high stocking rates not only resulted in poor animal production but also allowed steady weed invasion.

#### **Extension**

The necessity to identify target groups (commercial as well as smallholders) and to develop practical extension methods was regarded as crucial. Furthermore, it was viewed as important that technologies should be evaluated in cooperation with the target groups through on-farm research as early as practically possible. The importance of convincing the extension decision makers in Government of the value of new technology was acknowledged.

In Bali, close linkages between ACIAR collaborators from Udayana University and the Livestock Service have insured active extension of ACIAR forages technology. Planting materials have been widely disseminated through field days and KKN student practical work. More recently the Provincial Livestock Service have committed funds to assist with extension activities.

In Manado, the grazing trial at Lolak is being used for collaborative extension activities involving the Livestock Service and Sam Ratulangi University. The Livestock Service have committed funds in the 1995 budget to include ACIAR forages in their King grass nurseries.

The networking of international research and extension agencies also offered scope for more efficient dissemination of research findings, extension methodology, and distribution of seeds to national programs.

In Malaysia, the Department of Veterinary Services is the institution responsible for forages extension. Recommendations for extension of the hedgerow rubber system awaited finalisation of current research. Such recommendations will require changes in government policies. Packaged pilot programs were being developed with the collaborative involvement of several institutions. Farm managers and research staff will be involved in program evaluations.

*H.M. Shelton and B.F. Mullen*

## Research and Development Priorities

### Outcomes of Workshop Sessions

TWO SETS of recommendations for further research and extension were identified by participants at the ACIAR 9113 Round-up Meeting. Recommendations covered:

- a) forage systems for coconut plantations and
- b) forage systems for oil palm and rubber plantations.

Participants were divided firstly by their plantation crop interest and then each of these two groups were further split into sub-groups of six participants. These sub-groups appointed a chairman and secretary for reporting findings to the main meeting. This section summarises recommendations for future research priorities and future forage extension priorities.

### Future Research Priorities

#### Forage systems for coconut plantations

It was considered that several forage species for coconut plantations were able to be recommended for further on-farm evaluation. *Stenotaphrum secundatum*, *Brachiaria humidicola* and the *Arachis* spp. were considered the key species for grazed situations, with *Paspalum malacophyllum* and *Calliandra calothyrsus* for use as cut-and-carry species. However, further research was required to identify:

1. Low cost, rapid and effective techniques for vegetative establishment of all of these pasture species
2. Other tree legumes such as *Gliricidia sepium* and *Leucaena leucocephala* for planting with prostrate grasses under coconuts
3. Other legumes able to persist in combination with these grass species, especially among the range of *Arachis* spp. and accessions
4. Grazing/cutting management strategies to maintain vigorous growth of *Calliandra calothyrsus* and *Arachis* spp.
5. Superior cultivars or accessions of *Stenotaphrum secundatum* with respect to nutritive quality, anti-nutritive factors and animal production
6. The economic potential of strategic protein/energy supplementation of ruminants grazing under coconuts
7. The economic potential of nitrogen fertilised *Brachiaria decumbens* for communal grazing areas
8. The potential of *Arachis* spp. for use as cover crops under citrus and other plantation crops, for weed and erosion control and cut-and-carry forage production.

#### Forage systems for rubber/oil palm plantations

It was considered that no firm recommendations could be made regarding forages for sheep under rubber/oil palms, although MARDI had guidelines for cattle grazing under oil palm.

It was acknowledged that, given the low light transmission levels in mature rubber and oil palm plantations, the prospects for livestock integration into conventionally spaced rubber and oil palm plantations were limited, and that alternative planting systems held the best future prospects.

*Brachiaria humidicola* was identified as a grass species with great potential for the hedgerow system however, with the possible exception of *Stylosanthes guianensis* CIAT 184, no suitable legumes have been identified. Strategic use of supplements, including tree legumes and by-products, was promising but required further economic

analysis. Endoparasites were recognised as a major problem to the sheep industry. The ACIAR Project 9132 was identified as being an important source of information on control of endoparasites, and collaboration was encouraged where possible. Endoparasites and anthelmintic resistance are currently being researched by ACIAR Project 9132.

In North Sumatra, considerable progress had been made with regard to identification of suitable sheep breeds. There may also be a role for cattle either as the sole ruminant or in combination with sheep to reduce endoparasite burdens and to reduce the effects of patch grazing by sheep.

Further research was required to identify:

1. The optimal spatial arrangement for hedgerow rubber, making use of preliminary investigations using computer models currently being developed
2. New forage species (especially CIAT lines), with grazing animals being included in evaluation work at an early stage
3. The potential of *Pueraria phaseoloides* and *Paspalum notatum* for conventional spatial arrangements, including the weed control potential of *Paspalum notatum* under mature rubber
4. Grazing management strategies (including electric fencing and strip grazing) for sheep grazing *Brachiaria humidicola* and other forages with emphasis on regrowth potential, nutritive quality and endoparasite cycles
5. The economic potential of strategic supplementary feeding with locally available by-products and tree legumes
6. Whether legume mixtures (including tree legumes) or bag nitrogen best suit forage management
7. The most suitable crossbred sheep for the humid tropics with respect to resistance to parasites and liveweight production
8. Suitable establishment techniques for both seeded and vegetatively planted pastures.

### **Priorities for Forages Extension**

It was acknowledged that paradigms of effective technology transfer differed between Australia, Malaysia and the various provinces of Indonesia. Strongly 'top-down' communication channels were considered to be effective in Malaysia but less so in Indonesia. In North Sumatra in particular, farmer involvement early in the research process was considered crucial to successful identification of appropriate technologies and subsequent extension activities. As such the workshop sessions regarding extension priorities were dominated by Indonesia's requirements.

#### **Extension of forages for coconut plantations**

It was considered that a range of appropriate technologies were available for wider on-farm development. In Indonesia it was considered to be highly desirable to have Project extension messages accepted by the central government DGLS (Directorate General Livestock Services) extension system. Well researched, appropriate technologies can be widely and effectively disseminated by this system. Recommendations for extension of these technologies in Indonesia included:

1. The need for a pilot development phase to involve farmers and extension workers in on-farm testing
2. The requirement to convince the DGLS of the benefits of the forage systems identified

3. The establishment of further on-farm demonstration projects for extension and extension research purposes

4. The establishment of linkages with various agricultural development programs, e.g. IFAD, SR-CRSP, and strengthening of linkages with Government Departments e.g. Plantation Services (Dinas Perkebunan)

5. Continued production of extension materials, e.g. extension leaflets, videos, resource materials for extension officers

6. Further training programs for Province and District extension staff

7. Development of planting material multiplication sites to meet the likely demand for *Stenotaphrum secundatum* and *Arachis* spp.

Requirements for development of forage systems in the Philippines were similar to Indonesia. Other countries in the region had different requirements for development. Farmer credit problems, land ownership limitations and limited commercial market outlets for cattle in Laos and Vietnam and limited plantation areas in Laos were thought to be high priority issues.

### **Extension of forages for rubber/oil palm plantations**

#### *Malaysia*

Agricultural extension in Malaysia tends to follow a 'top down' approach in which technology packages are transferred to key plantations. For this reason, it is considered preferable to construct an entire, thoroughly tested, technology package for extension. Organisations such as RRIM achieve good results by field testing technology packages on managed cooperative estates or large individual estates monitored by estate and research staff. ACIAR 9113 research recommendations will be field tested in pilot development projects before extension recommendations will be made.

#### *Indonesia*

Indonesian researchers agreed that they had not yet identified clear messages to extend with respect to forages for rubber/oil palm plantations. However, the following points were made:

1. Monitored development projects should be commenced with existing 'best-bet' systems (research staff should be involved in initial extension activities)

2. These projects should involve farmers in the identification of technologies, with long term monitoring by extension officers

3. Government risk reduction schemes should be utilised

4. Reductionist research should continue to be carried out by research organisations

5. Research and extension linkages are improving but further improvement is required (plans are under way to physically link research and extension organisations in Indonesia)

6. Resource materials (seed, vegetative planting material) must be available for immediate distribution to farmers once appropriate species and technologies are identified

7. Extension and research staff should be involved in identifying the economic benefits/costs of technology packages.

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*B.F. Mullen*

## **New Pasture Species**

# Grass–Legume Mixtures for Coconut Plantations in Bali

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and W.W. Stür<sup>§</sup>

BALI'S cattle herd has increased steadily over the past ten years to reach 485000 head in 1993. Some 49000 head were marketed in 1993 with the majority of off-take being sold into Java. However, poor quality and weed-infested coconut pastures are limiting the potential of Bali's important cattle industry (Rika et al. 1991). Appropriate forage species are needed for smallholders which establish readily (preferably by vegetative means), are tolerant of heavy cutting/grazing regimes and strongly resist weed invasion (Stür and Shelton 1991). Persistence and productivity under shade and adaptability to either cutting or grazing systems are also desirable.

A wide range of grass and legume forage species and accessions was evaluated by Rika et al. (1991) under a heavy cutting regime in single plot experiments. Whilst the experimental design enabled a large number of species to be evaluated with relative ease, paddock variables such as competition effects in mixed pastures, palatability and tolerance of physical damage from grazing cattle could not be studied. Large-scale grazing trials are expensive so that the number of species combinations able to be tested was limited. The plot trials reported were therefore an intermediate phase of evaluation. The experiments aimed to evaluate the performance of grass–legume mixtures over a two-year harvest period for persistence, yield, grass–legume balance and susceptibility to weed invasion. This paper summarises the results from these experiments.

## Materials and Methods

The most promising species from the preliminary small plot experiments (Rika et al. 1991) were evaluated in grass–legume mixtures in grazed plots

(Experiment 1) (Table 1). To ensure that useful species were not missed, a wider range of species was selected and evaluated in grass–legume mixtures in small, cut plots sown with a common legume (Experiment 2). Experiment 3 used three grasses sown in combination with five legume species (Experiment 3, Table 1).

The trial was situated at the Udayana University research farm at Pulukan, Negara, 60 km west of Denpasar. The climate is humid-tropical with a distinct, three-month dry season and annual rainfall of 2100 mm. The coconut plantation was approximately 45 years old with 60% light transmission.

## Results and Discussion

Results from the two-year sampling period are summarised in Table 1. Dry season yields were the lowest in all experiments.

### Experiment 1

Average yields increased slightly in year 2 (data not presented), in contrast to Experiments 2 and 3. The explanation for this was not obvious but may be related to a higher residual leaf area under the grazing regime utilised in Experiment 1. Legume yields were also higher in Experiment 1.

The native pasture treatment had the lowest average annual yield. This treatment was dominated by annual grasses, *Imperata cylindrica* and broad-leaved weeds such as commonly occur in plantation situations throughout Bali (Rika et al. 1991). The *Paspalum malacophyllum* treatment was the highest-yielding, exceeding the native pasture treatment by 64%. It maintained green leaf long into the dry season and grew back rapidly at the break of the season. *P. malacophyllum* has an erect growth habit well suited to the cut-and-carry feeding system, however, it combined very poorly with legumes. Nitrogen fertilised *Stenotaphrum secundatum* Vanuatu (buffalo couch), was similarly high-yielding, but yield declined by 20% in year 2 (data not presented). The *Paspalum dilatatum* and *S. secundatum* Vanuatu + *Calliandra*

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**Table 1.** Species combinations, average DM yields and percentage legume contributions for experiments 1, 2 and 3.

Species mixture	DM yield (t/ha/yr)	Legume contribution (%)
<b>Experiment 1</b>		
Native forages	11.4	0
Native grasses + <i>Arachis</i> mixture <sup>a</sup>	13.5	18
<i>Stenotaphrum secundatum</i> Vanuatu + <i>Arachis</i> mixture	13.6	14
<i>Stenotaphrum secundatum</i> cv. Floratam + <i>Arachis</i> mixture	14.1	16
<i>Paspalum notatum</i> CPI 11864 + <i>Arachis</i> mixture	13.6	14
<i>Paspalum malacophyllum</i> CPI 27690 + <i>Arachis</i> mixture	18.6	6
<i>Paspalum dilatatum</i> + <i>Arachis</i> mixture	15.8	12
<i>Stenotaphrum secundatum</i> Vanuatu + <i>Calliandra calothyrsus</i>	15.9	14
<i>Stenotaphrum secundatum</i> Vanuatu (nitrogen fertilised)	18.5	0
<b>Experiment 2</b>		
<i>Paspalum malacophyllum</i> CPI 27690 + <i>Arachis pintoi</i> cv. Amarillo	15.3	6
<i>Paspalum wettsteinii</i> + <i>Arachis pintoi</i> cv. Amarillo	14.8	4
<i>Brachiaria humidicola</i> cv. Tully + <i>Arachis pintoi</i> cv. Amarillo	16.3	10
<i>Panicum maximum</i> cv. Gatton + <i>Arachis pintoi</i> cv. Amarillo	15.4	3
<i>Digitaria milanjiana</i> CPI 59775 + <i>Arachis pintoi</i> cv. Amarillo	17.7	3
<i>Stenotaphrum dimidiatum</i> + <i>Arachis pintoi</i> cv. Amarillo	15.6	9
<i>Axonopus compressus</i> (local) + <i>Arachis pintoi</i> cv. Amarillo	11.3	19
<i>Paspalum notatum</i> CPI 11864 + <i>Arachis pintoi</i> cv. Amarillo	12.4	12
<i>Stenotaphrum secundatum</i> Vanuatu + <i>Arachis pintoi</i> cv. Amarillo	14.1	13
<i>Paspalum notatum</i> cv. Competidor + <i>Arachis pintoi</i> cv. Amarillo	10.7	25
<i>Digitaria smutsii</i> + <i>Arachis pintoi</i> cv. Amarillo	13.8	14
<i>Brachiaria decumbens</i> cv. Basilisk + <i>Arachis pintoi</i> cv. Amarillo	14.1	14
<b>Experiment 3</b>		
<i>Paspalum malacophyllum</i> CPI 27690 + <i>Teramnus labialis</i> cv. Semilla Clara	17.2	4
<i>Paspalum notatum</i> CPI 11864 + <i>Teramnus labialis</i>	13.3	3
<i>Stenotaphrum secundatum</i> Vanuatu + <i>Teramnus labialis</i>	15.3	3
<i>Paspalum malacophyllum</i> + <i>Desmodium heterocarpon</i> CIAT 13119	15.8	3
<i>Paspalum notatum</i> + <i>Desmodium heterocarpon</i>	15.0	1
<i>Stenotaphrum secundatum</i> + <i>Desmodium heterocarpon</i>	17.7	3
<i>Paspalum malacophyllum</i> + <i>Arachis pintoi</i> cv. Amarillo	15.3	7
<i>Paspalum notatum</i> + <i>Arachis pintoi</i>	12.4	12
<i>Stenotaphrum secundatum</i> + <i>Arachis pintoi</i>	14.1	13
<i>Paspalum malacophyllum</i> + <i>Arachis glabrata</i> CPI 93483	16.5	8
<i>Paspalum notatum</i> + <i>Arachis glabrata</i>	15.1	17
<i>Stenotaphrum secundatum</i> + <i>Arachis glabrata</i>	17.4	16
<i>Paspalum malacophyllum</i> + <i>Desmodium ovalifolium</i> CIAT 13089	15.6	1
<i>Paspalum notatum</i> + <i>Desmodium ovalifolium</i>	14.2	4
<i>Stenotaphrum secundatum</i> + <i>Desmodium ovalifolium</i>	13.9	1

<sup>a</sup> *Arachis* mixture: *A. pintoi*, *A. repens* and *Arachis* sp. CPI 93483

*calothyrsus* treatments were also high yielding. Yields of legume-based buffalo couch treatments and *P. malacophyllum* increased in year 2, whereas yields of nitrogen fertilised buffalo couch, *P. dilatatum* and legume supplemented native forages declined by an average 14% in year 2 (data not presented).

Vanuatu buffalo couch spread more quickly than *S. secundatum* cv. Floratam due to the comparatively short internodes of cv. Floratam. *S. secundatum* cv Floratam may be of superior nutritive quality however, as it remained vegetative throughout the experiment, whereas the Vanuatu ecotype flowered over extended periods.

Treatments maintained reasonable legume contents throughout the experiment, with the exception of *P. malacophyllum*. In Experiments 2 and 3, the year 2 legume contents of buffalo couch and *Paspalum notatum* treatments were low (data not presented). This disparity may be related to extra residual leaf area under the grazing regime of Experiment 1. *Arachis pintoi* cv. Amarillo was the most productive of the *Arachis* species, however initial establishment and subsequent yields of *A. glabrata* and *A. repens* were poor. *A. glabrata* spread steadily over the experimental period whereas cv Amarillo did not. *Arachis* species combined well with all grasses except *P. malacophyllum*, possibly due to its erect habit.

*C. calothyrsus* was the highest yielding legume in year 2, increasing its yield from 1.5 t/ha in year 1 to 2.4 t/ha in year 2. No mortality of *C. calothyrsus* occurred during the experiment, however, in a related experiment where grazing was poorly controlled, Rika and Kaca (these proceedings) reported 100% mortality. *C. calothyrsus* may be better suited to cutting rather than grazing.

Weeds were of minor consequence, except in the native forages control, and plots became less weedy with time.

### Experiment 2

Average total yields dropped from 17.7 t/ha in year 1 to 10.9 t/ha in year 2, a decline of 39%. Yield decline may be particularly pronounced for shade-intolerant species (Shelton 1993) and initially high-yielding species (Stür 1991). Shelton (1993) suggested that truly shade-tolerant species experienced relatively minor yield decline over time.

*Digitaria milanijana* was the highest-yielding treatment overall but second year yield was poor. *Brachiaria humidicola* was the next highest-yielding treatment and its yield was comparatively stable. Several initially high-yielding treatments experienced a dramatic yield decline in year 2, including *D. milanijana*, *Paspalum wetsteinii*, *Panicum maximum* cv. Gatton and *Stenotaphrum dimidiatum*. *Axonopus*

*compressus* and *P. notatum* were the lowest-yielding treatments.

Average legume content fell from 18 to 5% in year 2. The *P. notatum* cv. Competidor treatment had the highest legume content but contribution declined from 33% in year 1 to 13% in year 2. All other treatments had a maximum of 7% legume by year 2. Weed contents declined over time with exception of the *Axonopus compressus* treatment which became increasingly weed infested.

### Experiment 3

Average yields of the three grasses were similar and all displayed excellent persistence despite minor yield declines in year 2. *P. malacophyllum* was the highest-yielding grass, although *P. notatum* experienced the lowest yield decline.

Legume yield declined from 3.1 t/ha/yr early in year 1 to 0.9 t/ha/yr in year 2. Only the *Arachis* spp, and in particular *A. glabrata*, displayed some persistence. Legume yields were generally poor in year 2 (data not presented). Weeds were of no consequence in any treatment.

## Conclusions

*P. malacophyllum* proved to be persistent and productive under heavy cutting and grazing treatments in small plots. Its erect growth habit make it well suited to cut-and-carry feeding systems. However, many of the erect grasses are prone to weed invasion under heavy grazing and the response of *P. malacophyllum* to grazing under field conditions requires investigation. It combined poorly with a range of prostrate and twining legumes.

Buffalo couch showed potential, being consistently productive, quick to establish from cuttings and forming a weed-free sward. Legume association with *C. calothyrsus* and *Arachis* spp. was acceptable.

*B. humidicola* satisfied the majority of the desired forage characteristics. It was productive and persistent under moderate shade and cutting regimes, weed-free in the second year, combined reasonably well with prostrate legumes and could be planted by vegetative means. Its use may be limited in intensive situations as it is not well suited to cut-and-carry harvesting.

*C. calothyrsus* showed promise as a fodder for cut-and-carry systems but its suitability to grazed systems requires further investigation. There has been great interest in the potential of the *Arachis* genus over the past 10 years. Results of the current experiment show that *Arachis* spp. are suited to heavily grazed, shaded pastures. Both the commercial cultivar 'Amarillo' and *A. glabrata* CPI 93483 showed most promise. These grass and legume species should be further evaluated in on-farm grazing trials.

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# Preliminary Evaluation of Grass–Legume Pastures under Coconuts in North Sulawesi

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IMPROVING the productivity and quality of forage resources for ruminants in North Sulawesi is essential to developing the cattle production potential of the province (Sondakh and Kaligis 1991). The shaded forage resource under coconuts currently consists of naturalised grass and weed species of low productivity (Kaligis and Sumolang 1991). Cut-and-carry feeding systems are not commonly utilised in North Sulawesi, with tethered and free-grazing more popular.

Kaligis and Sumolang (1991) recommended for further investigation a range of promising species identified from preliminary small, cut plot trials, harvested over a two-year period. A series of 'best-bet' forage species mixtures was selected from this species evaluation experiment for testing in larger plots under grazing (Experiment 1). Supplementary experiments were designed to investigate promising species not included in the 'best-bet' mixtures, including a range of grass species grown with a common legume (Experiment 2), and three grasses grown in combinations with four legumes (Experiment 3).

The experiments aimed to evaluate the performance of promising grass–legume mixtures in regularly grazed or cut plots, with respect to their persistence, yield, grass–legume balance and susceptibility to weed invasion. This report details results from the first 16 months of data and is an interim analysis only.

## Materials and Methods

The trial was situated at the Sam Ratulangi University experimental farm at Kayuwatu, Manado, North Sulawesi, Indonesia. The climate is humid-tropical,

generally with well-distributed rainfall and the soil is a moderately fertile sandy loam. For further details see Kaligis and Sumolang (1991). Coconuts were approximately 35 years old and were planted in a square pattern at 10 m spacings. Shade was estimated to reduce photosynthetically active radiation (PAR) to 55% of ambient.

Experiment 1 evaluated eight grass–legume treatments under regular grazing in 5 m × 5 m plots (Table 1). Experiments 2 and 3 evaluated grass–legume mixtures under a regular cutting regime in 2 m × 2 m plots (Table 1). Following a clearing cut (1 October 1992) at the end of a six-month establishment period, treatments were harvested every 8–10 weeks, depending on regrowth. After harvesting, the treatments were grazed in Experiment 1, and cut in Experiments 2 and 3 to the sampling height of 5 or 10 cm, depending on species. Samples were separated into sown grass, planted legumes, invading grass and legume species and broadleaved weeds. Harvests were grouped in periods of approximately 120 days corresponding to seasons. Data were analysed using the University of Queensland, QUASP statistical analysis program.

## Results and Discussion

### Experiment 1

#### Yield

Treatment yields were low in the harvest period 3, reflecting a period of lower rainfall. Most species experienced only minor yield reduction over time, however the *Brachiaria decumbens* (signal grass) treatment experienced marked yield reduction (Table 1a).

*Brachiaria humidicola* was the most consistent, high-yielding grass both in combination with legumes and with nitrogen fertilizer. The *Paspalum notatum* treatment became increasingly productive over time, and yield at the final harvest period was comparable with the highest-yielding treatments.

Native forages and *Stenotaphrum secundatum* cv Vanuatu treatments were low yielding over all harvest periods.

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**Table 1.** Species combinations and DM yields and percentage legume contributions from 4 harvest periods (HP).

Species mixture	DM yield (t/ha/month)				Legume contribution (%)			
	HP1	HP2	HP3	HP4	HP1	HP2	HP3	HP4
<b>a. Experiment 1</b>								
Native forages ( <i>Avonopus compressus</i> dominant)	0.9 d*	1.0 cd*	0.5 b*	1.0 b*	21	15	24	26
<i>Avonopus compressus</i> (local) + legume mixture <sup>a</sup>	0.8 d	1.1 cd	0.5 b	0.8 b	39	34	26	42
<i>Paspalum notatum</i> Competidor + legume mixture	1.1 cd	1.1 bcd	0.6 b	1.3 a	33	32	29	15
<i>Stenotaphrum secundatum</i> Vanuatu + legume mixture	0.9 d	0.8 d	0.6 b	1.0 b	32	32	33	26
<i>Stenotaphrum secundatum</i> Vanuatu + <i>Calliandra calothyrsus</i>	1.2 cd	0.8 cd	0.6 b	0.8 b	23	8	14	14
<i>Brachiaria decumbens</i> cv. Floratam + legume mixture	2.0 a	1.5 abc	0.6 b	0.8 b	1	0	0	1
<i>Brachiaria humidicola</i> CPI 27690 + legume mixture	1.5 b	1.5 ab	1.4 a	1.4 a	14	15	15	16
<i>Brachiaria humidicola</i> + nitrogen fertilizer (200 kgN/ha/yr)	1.4 bc	1.7 a	1.4 a	1.5 a	—	—	—	—
<b>b. Experiment 2</b>								
<i>Paspalum notatum</i> CPI 11864 + <i>Arachis pintoi</i> cv. Amarillo + <i>C. pubescens</i>	0.7 b*	0.7 d*	0.5 c*	1.1 b*	50	46	48	18
<i>Avonopus compressus</i> (local) + Amarillo + centro	1.0 b	0.7 d	0.4 c	0.7 bc	76	56	55	47
<i>Stenotaphrum secundatum</i> Vanuatu + Amarillo + centro	0.7 b	0.6 d	0.5 c	1.2 ab	45	49	50	9
<i>Brachiaria humidicola</i> cv. Tully + Amarillo + centro	1.6 a	1.5 c	1.2 b	1.4 ab	24	25	24	11
<i>Brachiaria decumbens</i> cv. Basilisk + Amarillo + centro	1.8 a	1.8 b	1.5 ab	0.9 bc	8	6	9	5
<i>Setaria sphacelata</i> cv. Splenda + Amarillo + centro	1.8 a	2.2 a	1.6 a	1.7 a	9	9	15	9
<i>Stenotaphrum secundatum</i> Floratum + Amarillo + centro	0.6 b	0.7 d	0.6 c	0.6 c	55	51	46	32
<b>c. Experiment 3</b>								
<i>Paspalum notatum</i> cv. Competidor + <i>Desmodium scorpiurus</i>	0.7 n.s.	0.6 f*	0.6 e*	0.9 n.s.	8	11	10	3
<i>Paspalum notatum</i> cv. Competidor + <i>Desmodium heterophyllum</i>	0.7	0.7 e	0.6 e	1.0	29	20	17	7
<i>Paspalum notatum</i> cv. Competidor + <i>Desmodium ovalifolium</i>	0.9	0.9 d	0.8 c	1.0	31	26	24	1
<i>Paspalum notatum</i> cv. Competidor + <i>Arachis glabrata</i> CPI 93483	0.7	0.8 e	0.6 de	0.9	8	9	11	6
<i>Stenotaphrum secundatum</i> (Vanuatu) + <i>Desmodium scorpiurus</i>	1.1	1.2 c	1.1 b	1.0	6	7	10	1
<i>Stenotaphrum secundatum</i> (Vanuatu) + <i>Desmodium heterophyllum</i>	0.9	0.9 d	0.7 d	1.0	41	38	35	12
<i>Stenotaphrum secundatum</i> (Vanuatu) + <i>Desmodium ovalifolium</i>	0.9	1.0 d	0.9 bc	1.0	36	33	32	5
<i>Stenotaphrum secundatum</i> (Vanuatu) + <i>Arachis glabrata</i> CPI 93483	0.6	0.7 ef	0.6 de	0.9	10	10	13	6
<i>Brachiaria humidicola</i> cv. Tully + <i>Desmodium scorpiurus</i>	1.5	1.6 a	1.6 a	1.3	6	4	4	3
<i>Brachiaria humidicola</i> cv. Tully + <i>Desmodium heterophyllum</i>	1.3	1.4 b	1.1 b	1.3	20	18	21	6
<i>Brachiaria humidicola</i> cv. Tully + <i>Desmodium ovalifolium</i>	1.1	1.0 d	0.9 bc	1.2	27	21	19	12
<i>Brachiaria humidicola</i> cv. Tully + <i>Arachis glabrata</i> CPI 93483	1.0	1.0 d	0.9 c	1.1	5	6	5	2

<sup>a</sup>Legume mixture: *A. pintoi*, *A. repens* and *Centrosema pubescens* CPI 58575

\* Treatment means with common letters are not significantly different ( $P > 0.05$ )

### Legume and weed content

The average legume contribution to dry matter (DM) yields remained stable over successive harvest periods (15–17%). *Arachis pintoii* and *A. repens* yields (averaged over all relevant treatments) were similar at approximately 1000 kg/ha/yr. *Centrosema pubescens* yields averaged 600 kg/ha/yr. *Calliandra calothyrsus* yielded poorly.

Native legumes *C. pubescens* and *Calopogonium mucunoides* (calopo) steadily invaded all plots and especially the native pasture treatment.

Weeds were of limited and decreasing significance over the experiment (data not presented). Legume species supplementing native forages effectively reduced weed invasion compared with the unsupplemented native forage treatment (5% and 33% weeds of DM respectively at harvest period 4).

### Experiment 2

#### Yield

Treatment yields declined over the first three harvests but increased with the more favourable growing conditions of the fourth harvest period. Yield of the *B. decumbens* (signal grass) treatment was initially high but declined continuously with successive harvests. The *Setaria sphacelata* treatment outdid all other treatments over the duration of the experiment and was least affected by dry periods (Table 1b).

Yields of *P. notatum* and *S. secundatum* cv Vanuatu and Floratum (buffalo couch) treatments were modest and comparable to the *Axonopus compressus* (carpet grass) treatment until the fourth harvest when the former treatments dramatically increased production in comparison with the carpet grass treatment.

### Legume and weed content

Legume yields were initially very high but declined over time. Legumes persisted strongly in *Axonopus compressus*, *S. secundatum* cv. Floratum and *P. notatum* CPI 11864 treatments. Legumes yielded very poorly in *B. decumbens* and *S. sphacelata* treatments. *Centrosema pubescens* (centro) was generally more productive than *Arachis pintoii* cv. Amarillo (Amarillo).

Weeds were only of significance in the carpet grass treatment, which was becoming progressively more weed infested (data not presented).

### Experiment 3

#### Yield

Harvest means followed the same pattern as Experiment 2. *B. humidicola* treatments were highest yielding at all harvest periods (Table 1c). Yields of *P. notatum*

and *S. secundatum* treatments at the fourth harvest period were higher than at other harvest periods.

### Legume and weed content

Legumes tended to combine more readily with buffalo couch treatments than with *B. humidicola* and *P. notatum* treatments. *Desmodium ovalifolium* combined with grasses more productively than *D. heterophyllum* and both of these outyielded *Arachis glabrata* and *D. scorpiurus*. The productivity of the *D. ovalifolium* declined dramatically over successive harvests and yields were below those of *D. heterophyllum* at the last harvest.

*D. ovalifolium* combined most productively with *B. humidicola*. *D. heterophyllum* combined well with all grasses but particularly buffalo couch.

Yields of *D. scorpiurus* were modest at all harvests and declined sharply in the fourth harvest period. Yields of *A. glabrata* were modest but consistent, but this species did not combine well with *B. humidicola*. Weeds were of no significance throughout the experiment.

## Discussion

*B. humidicola* was consistently high-yielding in all three experiments, both in combination with legumes and with nitrogen fertilizer. Yield fluctuation between harvest periods was minimal, and production during the dry harvest period 3 was comparably good. Reynolds (1988) reported *B. humidicola* to be of medium shade- and drought-tolerance but very tolerant of heavy grazing. The contribution of planted legumes to DM of *B. humidicola* treatments decreased with successive harvests. However, the *Arachis* spp., *D. ovalifolium* and *D. heterophyllum* (hetero) combined moderately well with *B. humidicola*. Centro and hetero have been reported to combine well with *B. humidicola* (Evans et al. 1992).

Unlike other high-yielding grasses in the experiments, the productivity of signal grass continued to decline in the fourth harvest (Table 1). Signal grass is reported to be of medium tolerance to shaded conditions (Reynolds 1988) and declining yield with progressive harvests was not unexpected, although there was a dramatic yield decline in Experiments 2 and 3. Signal grass was quick to smother out companion legumes and weeds. Species diversity was consistently lowest in signal grass and by the fourth harvest these treatments contained 95% signal grass.

Carpet grass treatments in Experiments 1 and 2 were over-run by planted legumes and invading grasses and weeds, and yield of the carpet grass fractions declined rapidly. The planted legumes, Amarillo and centro yielded well in these treatments, and together with invading grasses and weeds, these

species reduced the overall treatment productivity. Carpet grass is reported to maintain consistent, modest productivity under shaded conditions (Samarakoon et al. 1990) but is susceptible to weed invasion (Macfarlane and Shelton 1986).

*P. notatum* is widely reported as being a shade-tolerant grass (Stür 1991). Both accessions planted (cv. Competidor and CPI 11864) were slow to establish and tended to be weed infested during initial harvests. DM production from *P. notatum* treatments was comparable to the carpet grass treatments until the fourth harvest when the *P. notatum* treatments significantly outyielded the carpet grass treatments and weed content declined sharply. *P. notatum* swards at other sites have been reported as being very slow to establish, however the species eventually formed a dense stoloniferous mat which resisted legume and weed association (I.K. Rika, pers. comm.). This slow establishment phase may cause this species to be poorly accepted by smallholder farmers.

Of the two *S. secundatum* (buffalo couch) ecotypes planted, the Vanuatu line was very quick to establish in comparison to the Floratam cultivar. Floratam had stolons with comparatively short internodes. It did not flower at any time throughout the experiment. The Vanuatu ecotype flowered regularly over extended periods, undoubtedly reducing its nutritive quality. The yields of both lines were depressed by dense legume growth in early harvest periods and DM yields were only slightly superior to native carpet treatments. However, as the grass became strongly established, legume contribution dropped off markedly and total DM yields increased (Table 1). Buffalo couch treatments strongly resisted invasion by weeds and other grasses. This species has proved to be persistent and moderately productive in Vanuatu (Evans et al. 1992).

The *S. sphacelata* cv Splenda treatment outyielded all other treatments and was least affected by the dry harvest period three (Table 1b). The legume cv. Centro combined with Splenda more readily than did cv. Amarillo. Together these species contributed approximately 10% to DM. Invasion by other grasses and weeds was negligible. Splenda is known to be tolerant of heavy grazing and shaded conditions (Hacker and Williams 1993). It has a high fertility requirement however, being a tussock grass, it may be prone to weed invasion if subjected to repeated heavy grazing.

The yield and contribution to DM of the various legume species had not yet stabilised by harvest period 4. Amarillo, *A. glabrata*, centro, *D. ovalifolium* and *D. heterophyllum* all yielded reasonably well although their long-term persistence is uncertain. The productivity of the many legume species declined dramatically during the fourth harvest period. Yields of the *D. scorpiurus* treatments were

modest at all harvests. *C. calothyrsus* yielded poorly in comparison to reports by Mendra et al. (these proceedings).

## Conclusions

Preliminary evaluations indicate that most improved grasses significantly outyielded the naturalised grass *A. compressus* by the final harvest. *B. humidicola* and *S. sphacelata* cv. Splenda performed very well, with high yields, moderate legume association and strong resistance to weed invasion. Both of these species deserve further field testing under grazing.

The shade tolerant species *P. notatum* and *S. secundatum* ecotypes were comparatively slow to establish, but were persistent, combined moderately well with legumes and resisted weed invasion. Their DM production had not yet stabilised but was increasing. The ease of vegetative establishment of buffalo couch ecotypes and *B. humidicola* make these species more smallholder-appropriate than *P. notatum*, which is reported to be very slow to establish (Kaligis and Sumolang, these proceedings).

Signal grass performed poorly in the experiment. After successfully competing with most planted legumes, yield dropped dramatically with successive harvests. It may be expected that weed invasion would occur at future harvests (Kaligis and Sumolang, these proceedings).

Amarillo was initially high-yielding but productivity declined with time. *Arachis* species were persistent but of low productivity. Naturalised species centro and calopo were very productive under the moderate grazing regime. *D. heterophyllum* yielded well with a range of vigorous grasses. *D. ovalifolium* combined very productively with *B. humidicola*, but less well with other species. However, the rapidly declining yields of these two legumes over successive harvests indicated poor persistence. *D. scorpiurus* yielded poorly throughout the experiment, but combined better with *B. humidicola* than other grasses. *Arachis repens* was low yielding, but was persistent over successive harvests. It may be useful as one of a range of legumes planted in grass-legume pastures.

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# Evaluation of Grass-Legume Mixtures under Young Rubber in Malaysia

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EVALUATION of new forage species with potential to improve animal production under plantation crop systems is important for the continued development of the livestock sector in Malaysia (Tajuddin and Chong, these proceedings). Two experiments were conducted between 1988 and 1991 at the Rubber Research Institute of Malaysia (RRIM) experimental station at Sungai Buloh to identify new forage germplasm suitable for the plantation environment (Ng 1991). From the large number of accessions (accessed through CSIRO, Division of Tropical Crops and Pastures in Australia) evaluated in previous work, it was clear that some introduced forages had much higher yield potentials than the currently used cover crops and natural species at all light levels.

The best performing introduced species from these experiments are currently being evaluated as grass-legume mixtures under grazing in conventionally planted and 'core-stump' planted rubber. Core-stump rubber is raised in the nursery for 18 months before planting. This process reduces the field time to maturity by approximately 10 months. The period during which the rubber is susceptible to damage from grazing sheep is also greatly reduced. This paper reports some preliminary results from these experiments.

## Methods and Materials

### Location

Two experiments are being conducted at RRIM Experimental Station, Sungai Buloh. Edaphoclimatic information for the site is detailed by Chong and Tajuddin (these proceedings).

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### Experimental design and treatments

Randomised complete block designs were used for both experiments. Eight forage treatments were used for both experiments (Table 1), planted under 'core-stump' rubber (raised in nursery for 18 months before field planting) in Experiment 1 and under conventional young rubber (3-whorl polybag plants) in Experiment 2. The species were chosen to give a mixture of grasses and legumes for both high- and low-light conditions to provide continuity of yield as light transmission through the rubber declined with age.

### Rubber establishment

Rubber clone RRIM 901 was planted in July 1991 at 6 m × 4 m spacings in both experiments. Christmas Island rock phosphate (CIRP) was incorporated into the soil at a rate of 112 g/planting hole. Routine weeding and manuring as per standard plantation practice was followed. Trees lost due to root disease were replaced.

### Pasture establishment

Soil infertility at the experimental site was corrected with ground magnesium-limestone (2 t/ha), and CIRP (0.5 t/ha) applied as basal dressing. In addition, forage plots were fertilised with sulfate of ammonia (20 kg/ha), copper sulfate (4 kg/ha), zinc sulfate (5 kg/ha) and muriate of potash (200 kg/ha) at planting. The N-fertilised treatment (Treatment 8) was top-dressed with 25 kg N/ha after each grazing cycle.

Species which do not produce viable seeds or for which seed was not available were propagated by vegetative means. Cuttings were rooted in small polybags in the greenhouse and later transplanted into the experimental plots. Species propagated vegetatively were: *Stylosanthes guianensis* CIAT 184, *Stenotaphrum secundatum* cv. Floratam, *Brachiaria brizantha*, *Digitaria setivalva* and *Panicum maximum* cv. Vencedor.

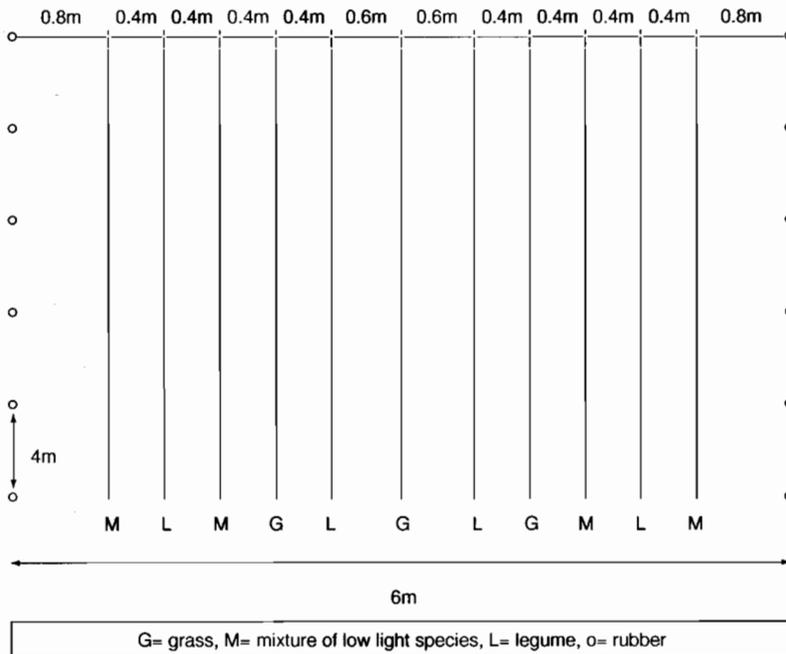
**Table 1.** Yield of the best-bet grass and legume mixtures in core-stump rubber.

Treatment <sup>a</sup>	Year 1 <sup>b</sup> (kg/ha)	Year 2 <sup>b</sup> (kg/ha)	% reduction in DM Year 1-2	Mean annual yield (kg/ha)
1. <i>P. phaseoloides</i> (control)	6.2	3.4	45	4.8
2. <i>P. phaseoloides</i> + <i>P. maximum</i> + low light mixture <sup>c</sup>	7.4	4.5	39	6.0
3. <i>P. maximum</i> + <i>Stylosanthes</i> sp. + low light mixture	8.1	5.1	37	6.6
4. <i>P. phaseoloides</i> + <i>P. maximum</i> + <i>Stylosanthes</i> sp. + low light mix.	8.5	4.5	47	6.5
5. <i>B. humidicola</i> + <i>Stylosanthes</i> sp. + low light mix.	9.0	6.9	23	8.0
6. <i>B. brizantha</i> + <i>Stylosanthes</i> sp. + low light mix.	9.5	12.1	(32)	10.8
7. <i>D. setivalua</i> + <i>Stylosanthes</i> sp. + low light mix.	8.1	4.6	43	6.4
8. <i>P. phaseoloides</i> + <i>B. humidicola</i> + low light mix. (N-fertilised)	10.6	6.6	38	8.6

<sup>a</sup>Grass and legume species were chosen to provide early growth under higher light. A low light species mixture of *Stenotaphrum secundatum* and *Arachis pintoi*.

<sup>b</sup>Year 1 May 1992–May 1993, Year 2 May 1993–May 1994

<sup>c</sup>Low light mixture = *Stenotaphrum secundatum*, *Paspalum wettsteinii*, *P. notatum* and *Arachis pintoi*.



**Figure 1.** Planting pattern for pasture treatments. For the legume cover crop control only 'L' rows were planted.

The conventional cover crop treatment *Pueraria phaseoloides* (Treatment 1) was planted in 4 drills spaced 1.2 m apart between rubber rows. A closer planting pattern was adopted for the grass-legume treatments (Treatments 2–8) (Fig. 1). Core-stump and conventional rubber pastures were planted in October 1991 and November 1991 respectively.

To ensure that the species mixtures were relatively pure, monthly weeding rounds were carried out. Weeding ceased when 80% of the species mixtures were established. Sheep commenced grazing forages in Experiment 1 20 May 1992 (core-stump rubber), 7 months after pasture establishment, while forages in experiment 2 (young rubber) were not grazed until 5 November 1993, two years after rubber planting.

### Measurements

Forage dry matter yield and species composition were estimated by cutting five 0.5 m<sup>2</sup> quadrats from a cutting strip across each of the rubber interrows. Tall growing species (*P. maximum* cv. Vencedor and *B. brizantha*) were cut at 12–15 cm above ground level to induce regrowth from the base. Low growing species were harvested at a cutting height of 5 cm above ground level.

Plots were sampled at 6-weekly intervals from March 1992 until June 1994 and sheep were brought in to graze following each sampling. Tall species not grazed down were cut back occasionally to encourage uniform regrowth.

The effect of grazing and increasing shade on the species changes and dry matter yield were monitored.

## Results and Discussion

### Experiment 1

The dry matter yields of the various treatments are presented in Table 1. There was a decreasing trend in overall mean yields from year 1 to year 2. Treatments (T) 1, 2, 3, 4, 7 and 8 had sharp yield reductions (more than 35%), whereas T5 had minor yield reduction and T6 had increased yield. The yield reduction was attributed to the drop in light transmission from 77% photosynthetically active radiation (PAR) in Year 1 to 59% PAR in year 2.

The mean dry matter yield for T1 (*P. phaseoloides*) was the lowest, while the other treatments exceeded 6.0 t/ha/yr. The treatments with the highest yields were T6 (*B. brizantha* + *Stylosanthes* sp.), T5 (*B. humidicola* + *Stylosanthes* sp.), and T8 (N-fertilised *B. humidicola* + *P. phaseoloides*).

Changes in botanical composition of the various species combinations in the respective treatments from harvests 1 to 3 are as shown in Table 2. The dominance of grass species over the legume species was evident for most of the treatments except for T1 and T7. The

reduction in legume content was exacerbated by the selective grazing of sheep for *Stylosanthes* sp. and *P. phaseoloides*. In T7, the proportion of *D. setivalva* and *Stylosanthes* sp. at harvest period 1 was 45:50, but this treatment was quickly invaded by weeds. *D. setivalva* requires a high nitrogen regime to persist in the infertile soils at the RRIM Experimental Station RRIES.

*P. phaseoloides* persisted poorly when planted in a mixture with grass because it was not able to withstand grazing pressure and was less competitive than the grasses. The bulk of the legume yield was contributed by *Stylosanthes* sp.. The low-growing shade-tolerant species gradually increased in T2, T3 and T4 in which *P. maximum* cv. Vencedor was the main grass species.

### Experiment 2

The grass-legume combinations in Experiment 2 were the same as for Experiment 1. However, the forages were not defoliated by sheep for the first 2 years. Some of the tall growing species e.g. *P. maximum* cv. Vencedor, *B. brizantha* were cut back 1 year after planting because these species were overgrown, and had lodged over the tree rows. This created problems in field maintenance and manuring of the rubber trees. Poor growth of rubber was observed as a result of stress due to competition from the forages planted.

Presentation dry matter yields are as shown in Table 3. The cumulative dry matter yields (Harvest 1) were low for some of the treatments with tall growing species (T2, T3 and T4) because these tall species were cut-back (see 'measurements') and fertilizer was not re-applied in the second year. However, the response of species to manuring was particularly evident in treatments 2, 5 and 7.

After grazing, a rapid change in species composition, from legume dominated swards to a grass dominated pasture was observed in treatments 2–8 (Table 4). In these grass dominant swards, the legume composition was reduced to 6–26%, while weed content increased in all treatments (except T6) from 0 to 17% (in harvest 1) to 13–80% (in harvests 4–5). The highest weed content was found in T1 (80%), followed by T7 (60%), T8 (50%), T3 (35%) and T4 (28%).

## Conclusions

The findings from Experiments 1 and 2 suggest that improved pastures should not be planted in conventionally planted young rubber plantations because of strong competition with the rubber trees.

The planting of improved pastures into core-stump rubber enabled earlier grazing, but the growth of rubber was also slightly affected. Furthermore, under core-stump rubber, the high productivity of improved pasture may not be sustainable as evidenced by the

**Table 2.** Botanical composition of the various grass-legume treatments planted in core-stump rubber.

Treatment	Yield (DM kg/ha)	Botanical composition (%)				
		Cover crop	Grass for high light	Legume for high light	Mixture for low light	Weeds
1. <i>P. phaseoloides</i> (control)	1120 <sup>a</sup>	99	0	0	0	1
	711 <sup>b</sup>	84	0	0	0	16
2. <i>P. phaseoloides</i> + <i>P. maximum</i> + low low light mixture <sup>c</sup>	1462	80	80	0	10	1
	952	1	74	0	22	3
3. <i>P. maximum</i> + <i>Stylosanthes</i> sp. + low light mixture	2218	0	67	23	8	3
	1047	0	72	14	12	3
4. <i>P. phaseoloides</i> + <i>P. maximum</i> + <i>Stylosanthes</i> sp. + low light mixture	2075	2	59	31	7	1
	910	0	76	9	12	3
5. <i>B. humidicola</i> + <i>Stylosanthes</i> sp. + low light mixture	1948	0	42	57	1	1
	1338	0	64	18	2	10
6. <i>B. brizantha</i> + <i>Stylosanthes</i> sp. + low light mixture	950	0	48	45	6	1
	2162	0	91	1	7	2
7. <i>D. setivalua</i> + <i>Stylosanthes</i> sp. + low light mixture	1814	0	45	50	4	1
	947	0	11	51	2	36
8. <i>P. phaseoloides</i> + <i>B. humidicola</i> + low light mix. (N-fertilised)	1478	0	61	30	10	1
	1314	0	98	0	1	1

<sup>a</sup>Figure 1st row : Harvest period 1

<sup>b</sup>Figure 2nd row : Harvest period 3

<sup>c</sup>Low light mixture = *Stenotaphrum secundatum*, *Paspalum wettsteinii*, *P. notatum* and *Arachis pintoi*.

**Table 3.** Dry matter yield of the various grass-legume treatments in conventional young rubber.

Treatment	Harvest 1 <sup>a</sup> (kg/ha/month)	Harvest 2 <sup>b</sup> (kg/ha/month)
	LT <sup>c</sup> 88%	LT 69%
1. <i>P. phaseoloides</i> (control)	379	289
2. <i>P. phaseoloides</i> + <i>P. maximum</i> + low low light mixture <sup>d</sup>	395	851
3. <i>P. maximum</i> + <i>Stylosanthes</i> sp. + low light mixture	394	654
4. <i>P. phaseoloides</i> + <i>P. maximum</i> + <i>Stylosanthes</i> sp. + low light mixture	378	667
5. <i>B. humidicola</i> + <i>Stylosanthes</i> sp.+ low light mixture	355	883
6. <i>B. brizantha</i> + <i>Stylosanthes</i> sp.+ low light mixture	1464	1135
7. <i>D. setivalua</i> + <i>Stylosanthes</i> sp.+ low light mixture	300	680
8. <i>P. phaseoloides</i> + <i>B. humidicola</i> + low light mixture (N-fertilised)	346	489

<sup>a</sup>Harvest period 1, October 1993–March 1994

<sup>b</sup>Harvest period 2, March 1994–June 1994 (fertilizer applied at beginning of harvest period)

<sup>c</sup>LT = light transmission

<sup>d</sup>Low light mixture = *Stenotaphrum secundatum*, *Paspalum wettsteinii*, *P. notatum* and *Arachis pintoi*.

**Table 4.** Botanical composition of the various grass-legume treatments in conventional young rubber.

Treatment	Yield (DM kg/ha)	Botanical composition (%)				
		Cover crop	Grass for high light	Legume for high light	Mixture for low light	Weeds
1. <i>P. phaseoloides</i> (control)	1457 <sup>a</sup>	100	0	0	0	0
	419 <sup>b</sup>	20	0	0	0	80
2. <i>P. phaseoloides</i> + <i>P. maximum</i> + low low light mixture <sup>c</sup>	1620	84	8	0	0	6
	1234	17	53	0	0	30
3. <i>P. maximum</i> + <i>Stylosanthes</i> sp. + low light mixture	1855	0	6	81	3	10
	948	0	53	9	3	35
4. <i>P. phaseoloides</i> + <i>P. maximum</i> + <i>Stylosanthes</i> sp. + low light mix.	1836	10	1	0	2	2
	968	9	60	0	3	28
5. <i>B. humidicola</i> + <i>Stylosanthes</i> sp. + low light mix.	2417	0	6	77	0	17
	1280	0	68	19	0	13
6. <i>B. brizantha</i> + <i>Stylosanthes</i> sp. + low light mix.	3780	0	100	0	0	0
	1646	0	100	0	0	0
7. <i>D. setivalva</i> + <i>Stylosanthes</i> sp. + low light mix.	2201	0	0	93	0	7
	986	0	21	26	2	60
8. <i>P. phaseoloides</i> + <i>B. humidicola</i> + low light mix. (N-fertilised)	1726	91	9	0	0	0
	708	6	44	0	0	50

<sup>a</sup>Figure 1st row: Harvest Period 1<sup>b</sup>Figure 2nd row: Harvest Period 3<sup>c</sup>Low light mixture = *Stenotaphrum secundatum*, *Paspalum wettsteinii*, *P. notatum* and *Arachis pintoi*.

severe drop in forage production as light transmission dropped from 77% to 59% PAR in one year.

*B. brizantha* produced high yields in both experiments but was poorly accepted by sheep. Its aggressive nature raised concerns regarding its negative effect on the growth of rubber trees. *P. maximum* cv. Vencedor and *B. humidicola* persisted in both experiments but their yields were quickly reduced as light transmission dropped. The legume contents of all treatments declined in both experiments.

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## **Forages Production in Shaded Environments**

# Practical Pasture Establishment under Plantation Crops

B.F. Mullen\*

NATIVE pastures under plantation crops throughout Southeast Asia are dominated by grasses of low productivity and quality and by weed species (Stür and Shelton 1991). Replacement of weed infested native pastures with improved pastures can improve ruminant liveweight gains by up to 250 % (Mullen 1993), however the costs of pasture establishment can be high. Techniques of pasture establishment vary greatly between socioeconomic farming groups, but all techniques should be reliable and cost effective. Pastures that establish rapidly are generally less prone to weed invasion and can be grazed earlier than pastures that establish slowly (Evans et al. 1992). Economic considerations often limit the degree to which optimum establishment conditions can be provided. This paper outlines currently used methods of pasture establishment in the humid tropics and suggests alternative techniques that may be worthy of investigation.

## Pasture Establishment

Cook et al. (1993) recognised two distinct phases of pasture establishment: (1) seed germination to emergence, and (2) seedling growth and survival. Where pastures are established using vegetative material a two-phase model is also valid: (1) transplanting to cutting establishment, and (2) growth and survival. The second phase, involving persistence and spread of pasture species, is heavily dependent on the provision of optimal conditions for phase 1. Preparation for planting aims to remove or reduce competition from existing vegetation for light, nutrients and moisture and to ensure good seed/vegetative set-soil contact (Evans et al. 1992).

Insufficient soil moisture following planting is the most common reason for failure of newly planted pastures in Australia (Silcock and Johnston 1993). However, effective ground preparation (Cook et al. 1993) and in particular, removal of plant competition (Aminah et al. 1989) can improve establishment

under low moisture conditions. Regular and reliable rainfall in the monsoonal and humid tropics reduces the risk of establishment failure from low soil moisture. In such favourable climatic environments, native species grow rapidly and compete strongly with emerging pasture species. Effective ground preparation will prevent the risk of native species competition with seeded or vegetatively established pastures.

## Conventional Ground Preparation

The most reliable method of pasture establishment involves conventional ploughing and harrowing to remove all plant competition and produce a fine seed-bed (Cook et al. 1993; Wong and Sharuddin 1981). Deep cultivation is not required, as pasture seed is usually planted at a shallow depth, between 10 and 20 mm (Evans et al. 1992). The objective of cultivation is to remove existing vegetation and provide a firm surface layer of fine soil tilth into which seed or sets can be planted. Where machinery is used, offset disc harrows are preferred as they handle rocks, coral and sticks better than rotary hoes or tined implements. Disc harrows work most effectively cutting into short vegetation and can be operated at relatively high speeds (5–8 km/hr). At least two passes in opposite or perpendicular directions are required, followed by levelling with a heavy chain harrow. Conventional, mechanised ground preparation is expensive and is not suited to steep slopes prone to erosion.

Draught animals are commonly used for ground preparation throughout Southeast Asia. Ploughs tend to be mouldboard types designed to turn the soil over (Sumanto et al. 1993) and specific implements for ground preparation suitable for pasture planting are not available. Two ploughing operations are common and require approximately 45 working hours per hectare (over 15 days) for the two passes (Santosa et al. 1993). Costs are often high and therefore cheaper alternative ground preparation techniques are desired (Table 1).

Where possible, ploughing operations should be performed during hot, dry weather to achieve maximum kill of existing vegetation. A time period of at

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least one week should elapse before the second ploughing is performed so that exposed vegetation desiccates before being reburied. Such preferred ploughing conditions do not always exist and where continued rain follows the first pass, a decision must be made as to whether planting should proceed or be postponed. Another common problem encountered in pasture development under coconuts is the constant shedding of palm fronds which interfere with ploughing operations. Where fast emerging vigorous pasture species are being used immediate planting was found to be the best option (Evans et al. 1992).

### Planting From Seed

Pasture seed can be planted by drilling with a combine or direct drill planter, or by broadcasting with a fertilizer spreader, or by hand. Hand sowing is quick and cost effective for areas up to 30 ha. Each worker must throw seed to cover a width of 4 to 5 m and the paddock should be marked in 15 to 25 m wide strips accordingly (Macfarlane et al. 1991). Teams of three to five workers are most efficient. Sawdust or river sand can be used as a carrier for the seed to make a total mix of approximately 200 L by vol/ha. Experienced workers can plant 1.5 to 2 ha/person/day.

Fertilizer spreaders can sow between 20 and 40 ha/day. Sand or sawdust carrier is often used in conjunction with the spreader choke plate and tractor speed is used to regulate the planting rate. The planting rate should be constantly checked as humidity changes can affect the flow rate of the seed mix.

Irrespective of the sowing technique, all seed planted should be incorporated with a roller or chain harrow on the same day. Rollers are more effective than chain harrows and best of all are rollers with front mounted chains to provide some incorporation before roller action. In this way good seed-soil contact is

achieved. Small areas of seed can be incorporated by sweeping the area with rakes or coconut fronds.

Planting failures from poor quality seed are common. Pastures species such as *Brachiaria humidicola* and *Paspalum notatum* are renowned for their poor establishment from seed. A recent germination test should be sought to ascertain seed quality so that planting rates can be adjusted if necessary.

### Planting From Vegetative Sets

Planting from vegetative sets is the most reliable pasture establishment method for farmers without access to machinery. Sets should be as fresh as possible and planted into good soil moisture. Sets should be selected from regularly grazed or slashed, strongly vegetative material and not from flowering or tall swards. Commonly, grass sets are planted on a 1 m × 1 m grid pattern. Where the soil surface is dry, or follow-up rain is uncertain, planting holes should be deep enough to ensure that the sets maintain adequate moisture. Grass sets are more robust than legume cuttings. Legume cuttings desiccate rapidly and should be planted during periods of showery weather (Macfarlane et al. 1991).

### Alternative Ground Preparation

Numerous manual planting techniques suitable for smallholders were developed in the South Pacific (Macfarlane et al. 1994) and have potential for use in smallholder farming systems throughout the humid tropics. Generally the resultant pasture production reflects the level of inputs. However, it is desirable to have forage establishment techniques appropriate to the wide range of farming systems that exist. Relative inputs of labour and capital available for pasture production vary for different socioagricultural systems.

**Table 1.** Variable costs associated with pasture establishment.

Operation	Work-rate	Variable cost/ha	Reference
Disc harrowing (2m width)	0.5-1 ha/hr	4-8 L fuel	Mullen (1993)
Chain harrowing (4m width)	1.5-2 ha/hr	1 L fuel	Mullen (1993)
Draught animal ploughing	0.02 ha/hr	45 plowing hr	Santosa et al. (1993)
Zero-till planting (2m cover)	0.5-0.75 ha/hr	4 L fuel	Mullen (1993)
Manual glyphosate spraying		1-1.5 labour days	Mullen (1993)
Manual pasture seeding		0.5-0.7 labour days	Mullen (1993)
Manual vegetative planting			
<i>Stoloniferous</i> species		15-20 labour days	Mullen (1993)
<i>Pennisetum purpureum</i>		10 labour days	Crowder and Chheda (1982)

### **Direct drill planters— high capital/low labour**

Numerous tractor mounted, direct drill planters are available. All involve the metering of seed into a drill cut into existing vegetation, usually with a following herbicide band to remove competition. The sprayed layer of vegetation reduces the emergence of weeds between drills. Direct drill planters are particularly favoured in erosion-prone sites as there is no requirement for cultivation. Planting costs are generally slightly lower than conventional planting costs and the planting operation is less affected by excessive soil moisture. The direct drilling technique may have potential for seeding pastures into rubber plantations in Malaysia.

### **Hoof action — low capital/low labour**

In Vanuatu, Macfarlane et al. (1994) reported successful pasture establishment using trampling action to prepare planting sites. Cattle in excess of 10 head/ha were introduced into paddocks of up to 4 ha in size during the wet season. Over a 1–2 week period, continued hoof action on the friable soils caused sufficient disturbance for planting of pasture seeds. Cattle were left in the paddock overnight following planting to incorporate seed into the soil. This technique proved to be effective and reliable on clay-loam soils and in high rainfall regions (2300 mm+). Fences must be strong enough to prevent cattle from breaking out as feed becomes scarce. Tethered cattle can be used in much the same way to produce circular planting sites around coconuts which can then be planted to vegetative sets.

### **Oversowing into cow dung — low capital/low labour**

Where cattle graze permanently in one paddock, oversowing with vegetative sets of grass and/or legumes can be carried out by utilising the cattle's avoidance of grazing around dung pats. (Macfarlane et al. 1991). Following planting into semi-fresh dung pats cattle will not graze a vegetative set for up to 8 weeks. Fresh cow manure may be applied after 6 weeks if the sets have not fully established. This technique worked effectively for overplanting buffalo couch (*Stenotaphrum secundatum*), hetero (*Desmodium heterophyllum*) and Pinto peanut (*Arachis pintoi* cv. Amarillo) into T-grass (*Paspalum conjugatum*) pastures in Vanuatu and was also successful in North Sulawesi. The great advantage of this technique is that it can be done gradually and requires no major time commitment.

### **Strip planting of vegetative sets — moderate capital/moderate labour**

Given the aggressive nature of improved pastures, a common practice has been to plant vegetative sets

in strips with the expectation that the pasture species will spread from the strips. Competition can be removed from the strips by a variety of methods including: (1) hoeing out existing vegetation, (2) poisoning strips of vegetation with glyphosate (1% solution in water at 300L/sprayed ha), or (3) burning coconut fronds in lines. Rate of establishment to full cover will depend on the pasture species planted, the amount of remaining vegetation and the distance between planting lines (Table 2).

Further opportunities for alternative pasture establishment techniques may arise occasionally. For example, bare ground following a severe drought or intense fire may be used as a seedbed. Astute managers may benefit from such circumstances. However, the most reliable method of pasture establishment remains the conventional cultivation technique followed by pasture planting into a full profile of soil moisture.

## **Post-plant Weed Control**

Timely post-plant weed control can encourage rapid pasture establishment and minimise later weed control requirements. Options for weed control include hand weeding, spot spraying with non-selective herbicide, spraying with selective herbicide, short periods of heavy, non-selective grazing or by allowing climbing weeds to smother weed growth.

Hand weeding may only be cost-effective where labour costs are low, but it is the most discriminating weed control option. The area weeded daily per worker is often low and large work-forces may be required for timely weed control.

Spot spraying with a non-selective herbicide such as glyphosate can increase the rate of area controlled but has associated chemical costs. Selective herbicides such as 2,4-D are considerably cheaper and are effective on many broadleaved weeds. Most legumes are tolerant of low rates of 2,4-D once they are established (siratro and Shaw vigna are exceptions) (Evans et al. 1992). Pre-emergent herbicides cannot be used when seeding grass–legume mixtures.

Heavy, short-duration grazing with cattle is an effective method of reducing light competition to emerging pasture species. Stocking rates must be high enough to prevent selective grazing. The technique relies on the ability of the pasture species to regrow more quickly than weed species and is commonly used in combination with other weed control techniques.

The use of smothering legumes to control weeds is only possible in specific situations and where early grazing is not a necessity (Macfarlane et al. 1994). Legumes such as *Pueraria phaseoloides* and *Dolichos lablab* have been used in this way. A delicate

**Table 2.** Time to full pasture cover following planting into glyphosate sprayed vegetation.

Spraying method	Dominant existing vegetation	Percentage of area sprayed	Time to full cover (months)
Spot	<i>Axonopus compressus</i>	25	18–24
Strip	<i>A. compressus</i>	50	9–10
Blanket	<i>A. compressus</i>	100	3
Spot	<i>Paspalum conjugatum</i>	25	36+
Strip	<i>P. conjugatum</i>	50	18–30
Blanket	<i>P. conjugatum</i>	100	3

Source: Macfarlane et al. 1994.

balance must be maintained between smothering weeds and maintaining the growth of pasture species.

Mechanical or hand slashing of weedy pastures reduces weed competition and encourages the spread of prostrate pasture species. Efficient tractor slashing can be performed at a rate of 1 ha/hr. Slashers require a high level of maintenance, and a similar result can be achieved by heavy grazing by cattle over 5–10 days. Weed growth can be severely checked if slashed at the heavy flowering-early seed filling stage. Slashing of weeds during vigorous vegetative growth may have little effect.

## Conclusions

Improved pastures can dramatically improve ruminant production but the costs of pasture improvement are often high in terms of capital, labour or both. Pastures will establish rapidly and reliably where competition for light, moisture and nutrients is minimised and vegetative germules achieve good seed-soil contact. Conventional ground preparation best satisfies these requirements but is expensive. In smallholder situations, the use of vegetative planting material is commonly more reliable than pasture seed.

A range of alternative pasture planting techniques have been identified which are less demanding in terms of capital and labour, but pasture establishment may be less rapid and reliable.

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# Estimating Potential Yield of Forage under Plantations

J.R. Wilson\* and T. Schwenke†

PLANNING the integration of grazing ruminants with plantation crops could be greatly helped by reliable estimates of potential herbage growth rates as plantation growth affects light transmission. Such estimates of potential herbage growth rates and yield over monthly, or other designated regrowth periods, adjusted to give the proportion of leaf (the main component eaten), may be combined with animal daily intake requirements to predict a sustainable stocking rate for cattle or sheep. This paper, however, is concerned only with the initial prediction of potential herbage yield. The prediction is based on measurements, for several pasture types and defoliation regimes, of the proportion of incident photosynthetically active radiation intercepted by growing pasture over variable time intervals, and the efficiency with which this radiation is converted to above ground biomass. A small data set is used here, together with incident radiation for various localities, as inputs into a simple model to estimate maximum potential yield under coconuts at Manado, North Sulawesi, and under conventional and hedgerow rubber near Kuala Lumpur, Malaysia.

## Procedure for Estimating Yields

Pasture yield predictions may be made using a simple growth equation (Wilson and Ludlow 1991). The model requires initial knowledge of the incident radiation above the tree canopy. This information is as monthly averages of total daily short-wave radiation (SW) is found in climate station summaries (e.g. FAO 1987). This incident SW is converted to photosynthetically active radiation (= 0.5SW) for which the current term is photon irradiance (PI) and the preferred units are MJ/m<sup>2</sup>/day (assuming 1E of natural daylight is equivalent to 0.23 MJ). Monthly average values for incident daily PI for five experimental sites are shown in Table 1.

The proportion of this radiation incident on the understorey pasture is then derived from measurements of percent PI transmission in coconut and conventional rubber plantations of different ages (Wilson and Ludlow 1991). Ideally, light should be measured by PI meters which can integrate the spatial variability under the plantation canopy (e.g. Moss 1992). For hedgerow rubber, with east-west planting the area was divided into two sections: (a) one section of pasture with no canopy cover [= 100% light transmission]; this area was calculated assuming tree canopy spread into the interrow from each side of 3 m, 4.5 m and 8.5 m for 3-, 6- and 12-year-old trees (I. Tajuddin, pers. comm.); and (b) the under-canopy area which was assumed to be at the light transmission for 3-, 6- and 12-year-old trees. Potential yield for sun and shade area was calculated separately using the appropriate LUE and LI values (Table 2) and then summed. For monthly yield estimates of mature (6 and 12 yr) and, more importantly young (3 yr) conventional and hedgerow rubber, (especially the 3 yr), account was taken of change in light levels month by month, and of the overwintering period when light levels increase slightly (Tajuddin et al. 1990).

The simple equation was applied:

$$\begin{aligned} \text{Pasture growth (G)} & \text{ (g dry matter/m}^2\text{/day)} \\ & = \text{Light intercepted (LI) (MJ/m}^2\text{/day)} \\ & \times \text{Light use efficiency (LUE) (g DM/MJ)} \end{aligned}$$

LI is measured (using linear probes placed at ground level at weekly intervals for any chosen regrowth period e.g. 4–8 weeks). It is expressed as percent of PI intercepted relative to incident PI above the grass canopy. LUE is the conversion efficiency of PI to dry matter (g) of above ground herbage. Further details are in Wilson and Ludlow (1991).

LI and LUE have been determined for erect and prostrate forms of grass and legume pastures under conditions of adequate water in experiments in Southeast Queensland. Table 2 gives an example of data for an erect species, green panic (*Panicum maximum* var. *trichoglume* cv. Petrie), grown under different shade levels at high N supply, combined with data at low N for *P. maximum* cv. Guinea from an earlier experiment at the same site (Sopphanodora 1989).

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Note that LI remains reasonably constant down to about 30% light as the grass adjusts morphologically to increased light capture (Wong 1991) by increasing resources allocated to leaf growth (higher shoot:root ratio, leaf weight ratio and leaf area ratio), and produces thinner, larger leaves (high specific leaf area). LUE (for production of above ground herbage) increases as light decreases to about 50% because of increase in shoot:root ratio and higher foliar N% (Wong 1991), and because photosynthetic efficiency (g CO<sub>2</sub> fixed / unit PI = slope of photosynthesis light response curve) increases as incident light decreases (Wilson and Ludlow 1991). These changes are an attempt by the plant to compensate for increasing shade, but note that LUE and LI do not appear able (at least in *P. maximum*) to further change below about 50% and 30% light, respectively.

The LUE and LI data for green panic have been used to estimate potential herbage growth under 'tall' coconuts at Manado and under rubber at Kuala Lumpur. Estimates are shown as annual yields over 0–30 years (Fig. 1) or monthly yields for 3-, 6- and 12-year-old plantations (Table 3). The annual yields were derived from the summation of 6.5 two-monthly regrowth intervals, and monthly yields

were calculated using LUE and LI values for 8-week regrowths of green panic (T. Schwenke, unpublished data). For conventional rubber it was assumed that only two-thirds of the area would grow pasture and yields were discounted 33% to allow for this. Under hedgerow rubber, with trees in double rows 3 m apart, and 22 m between each double row it was assumed that the 3 m area between the trees in the double row and 1 m on the open area side of each tree row was unavailable for pasture, i.e. 5 m for each 25 m unit. Thus, pasture yields for hedgerow were discounted 20%. Under coconuts the whole area was assumed to be available for pasture growth.

At Kuala Lumpur, rainfall is high in all months (Table 1), except June–August when rainfall exceeds evaporation by only 12–20 mm. Yields in these months were discounted by 20% (Table 3). Perhaps in sandy soil sites such as at Sungai Buloh the adjustment for water stress could be greater. Climatological description for Manado (FAO 1987) lists 81 intermediate dry days; August–October is dry (Table 1) with rainfall minus evaporation values of –26, –28 and 2 mm, respectively. For these months, yields were discounted by 30, 30 and 20%,

**Table 1.** Average monthly incident radiation and rainfall for artificial- and tree-shaded experimental locations in Indonesia (Manado, N. Sulawesi<sup>a</sup> and Pulukan, Bali<sup>b</sup>), Malaysia (Kuala Lumpur<sup>a</sup>) and Southeast Queensland, Australia (Narayan and Samford<sup>c</sup>).

	PI <sup>d</sup> (MJ/m <sup>2</sup> /day)					Rainfall (mm)				
	Kuala Lumpur (3.1°N)	Manado (1.3°N)	Bali (8.4°S)	Narayan (25.6°S)	Samford (27.3°S)	Kuala Lumpur (3.1°N)	Manado (1.3°N)	Bali (8.4°S)	Narayan (25.6°S)	Samford (27.3°S)
Jan.	8.9	9.1	9.6	11.9	10.8	167	444	263	106	163
Feb.	9.7	9.6	10.4	10.4	9.2	157	358	236	96	160
Mar.	10.0	9.9	10.5	10.2	9.1	229	297	221	72	139
Apr.	9.7	10.2	10.5	8.9	8.0	278	216	171	37	81
May	9.4	9.9	9.0	7.0	6.2	196	177	145	39	66
June	8.7	9.3	8.8	6.3	6.0	131	175	76	37	60
July	8.9	9.9	8.8	7.0	6.4	129	139	68	36	55
Aug.	9.2	10.8	9.4	8.3	7.9	142	113	56	27	32
Sep.	9.0	11.0	10.8	10.2	9.3	185	106	123	34	46
Oct.	8.9	10.9	11.4	11.4	10.1	269	138	228	56	85
Nov.	8.2	9.9	11.3	12.2	11.6	278	240	214	77	91
Dec.	8.0	9.4	10.4	12.5	12.3	230	370	273	100	122
Average	9.1	10.0	10.1	9.7	8.9					
Total						2391	2773	2074	716	1106

<sup>a</sup>FAO (1987).

<sup>b</sup>Radiation data for Rogodjampi (FAO 1987) a nearby site on Java, rainfall for Pulukan, Bali (Shelton and Stür 1991).

<sup>c</sup>Cook and Russell (1983).

<sup>d</sup>Photosynthetically active radiation (Photon irradiance, PI) calculated as 0.5 short-wave radiation (Sziecz 1974).

**Table 2.** Light use efficiency (LUE) and cumulative light interception (LI) for 8-week regrowths of *Panicum maximum* grown under different light levels<sup>a</sup> and high or low nitrogen supply.

Light transmission (%)	LUE (g tops DM/MJ of PI <sup>b</sup> )		LI (% of incident PI <sup>b</sup> )	
	+N <sup>c</sup>	-N <sup>d</sup>	+N <sup>c</sup>	-N <sup>d</sup>
100	2.7	1.2	75	63
70	3.1	1.3	75	66
50	3.4		70	
30	3.4 <sup>c</sup>	2.6	70 <sup>c</sup>	68
15	3.5		50	

<sup>a</sup> Grown at Redland Bay, Southeast Queensland with adequate water.

<sup>b</sup> PI = photon irradiance (photosynthetically active radiation, PAR) expressed as MJ/m<sup>2</sup>/day.

<sup>c</sup> T. Schwenke, unpublished data for *P. maximum* var. *trichoglume* cv. Petrie.

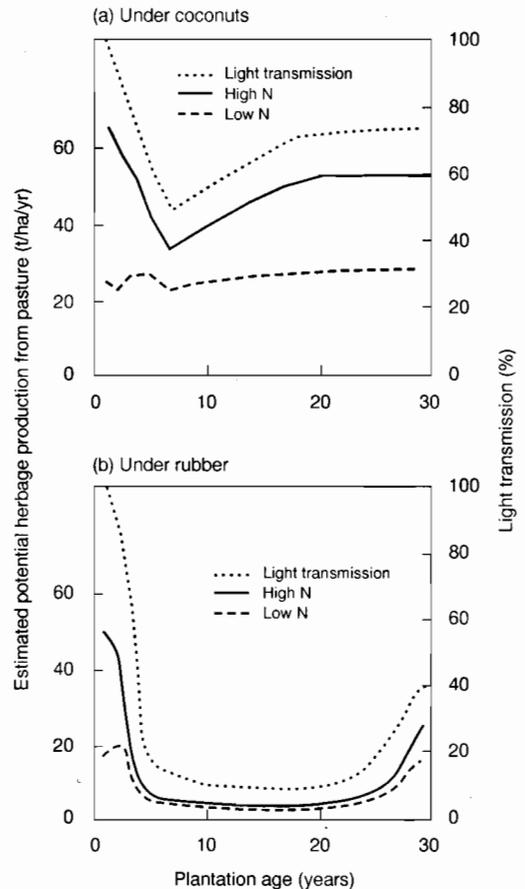
<sup>d</sup> Data from Sophanodora (1989) for guinea grass (*P. maximum* cv. Guinea).

respectively. Rainfall for the Bali site (Table 1) is low for at least 5 months and thus would need a larger discount for water stress than for Manado. A sound basis for discounting yield for water stress is needed. Eventually, values for LUE and LI under water stress conditions may be obtained for shaded pastures under plantations to use for yield calculations. Values for crop plants in full sun (Wilson and Ludlow 1991) indicate a reduction in LUE from 5–33% under water stress.

## Annual Yield Potential

Figure 1 indicates that in full sun at high N, potential annual yields are 65–75 t DM/ha/yr for both the Manado and Kuala Lumpur sites. These yields were not discounted for water stress as were the monthly yields, so they represent the maximum response to light level. Such values, although appearing very high, are in the region of 66–85 t DM/ha/yr for *Pennisetum purpureum* and 49 t/ha/yr for *P. maximum* measured for open sun, well-watered, high N pastures in Puerto Rico (Cooper 1970), a site with a 12-month growing environment. Maximum yields at low N in full sun were 22–25 t/ha/yr. For Kuala Lumpur, the yields at low N in sun and young rubber (2–5 yr) are probably over-estimated for Sungai Buloh because the sandy soils there are more infertile than the unfertilised kraznosem soil at Redland Bay.

Under coconuts, the maximum potential yield declines rapidly in response to light to a minimum of 35 t/ha/yr at age 7, rising to about 50 t/ha/yr in mature plantation. Again, these potential yields seem high,



**Figure 1.** Estimated potential annual herbage dry matter yields of grass pasture for high and low nitrogen situations under coconut plantations at Manado, N. Sulawesi and under conventional rubber plantations near Kuala Lumpur, Malaysia; calculations based on LUE and LI for 8-week regrowths of green panic (Table 2) and PI light transmission curves (.....) from Wilson and Ludlow 1991.

although comparison with data from the experimental sites presented in Shelton and Stür (1991), shows that one species at the Manado site, *P. maximum* cv. Riversdale, yielded 47 t/ha/yr (Kaligis and Sumolang 1991). The low N yields showed little response to light and stabilised at about 25 t/ha/yr. These yields may be compared with measured yield under mature coconuts at Manado (Kaligis and Sumolang 1991) and Bali (Rika et al. 1991). Because of frequent cutting and removal of N in herbage, minimal replacement N fertilizer, and high rainfall at the sites, the yields reported by these authors may be regarded as from a low N situation. The estimated yield (Fig. 1) is a little

higher than actual yields of green panic of 17.7 t/ha/yr at Manado and 19.2 t/ha/yr at Bali but not very different from the 22.5 t/ha/yr for *P. maximum* Riversdale and 24.5 t/ha/yr for *P. maximum* cv. Gattan at Bali. The light transmission curves used in these calculations, and the experimental sites for data collection, were in 'tall' coconut plantations. In plantations of hybrid palms, % PI transmissions may be much lower, e.g. from 35–55% in different months for 13-year-old trees at 142 stems/ha, and as low as 21–45% for 8-year-old high potassium fertilised trees (Moss 1992). Calculated pasture yields would thus be lower under hybrid or dwarf coconut cultivars than those shown in Table 3 and Figure 1.

Under rubber, maximum possible annual yields are high only in years 1–3 and drop rapidly to a base yield of about 8 t/ha/yr in a mature plantation at year 6 (Fig. 1). Importantly, at light levels below 20% there was virtually no difference between high and low N situations, so little benefit appears to be gained by adding N fertilizer in mature rubber. The estimated 8 t/ha/yr maximum (without water stress) compares moderately well with the highest measured annual yields under 4-year-old rubber of 5.0 t/ha for guinea grass and 6.5 t/ha for signal grass (Sophanodora and Tudsri 1991), and 6.1 t/ha for *P. maximum* under rubber at 26–50% light (Wong

1991). However, it is much higher than measured yields of 1.3–2.3 t/ha/yr in 5-year-rubber (Sophanodora and Tudsri 1991), and of 1.2–4.2 t/ha/yr at <25% light (Wong 1991).

Green panic is a fast-growing erect species and LUE and yields for 8-week regrowths at higher light levels as shown in Figure 1 are substantially higher than those calculated for 4-week regrowths or for the shade-tolerant mat-forming grass *Paspalum notatum*, but these differences between defoliation frequency and species largely disappeared at the much lower light levels under mature rubber (T. Schwenke, unpublished data).

Annual potential pasture yields under conventional rubber as predicted by Abd. Samat (these proceedings), are lower than those reported here. Abd. Samat derived yields based on potential yields of native pastures, for which it is assumed that light interception is one-third of that by introduced pastures.

### Monthly Yield Potential

These data are probably more useful than annual yields because they provide a basis for adjustment of animal carrying capacity to seasonal change in pasture growth. In the wet tropics, average temperature and incident radiation show little change month-to-

**Table 3.** Estimated maximum monthly yields<sup>a</sup> (t DM/ha) for green panic (*P. maximum* var. *trichoglume*) under coconuts at Manado<sup>b</sup> and conventional and hedgerow planted rubber plantations in Kuala Lumpur environs<sup>b</sup>.

	Coconut		Conventional rubber <sup>c</sup>		Hedgerow rubber <sup>c</sup>		
	3-yr-old	6-yr-old	3-yr-old	6-yr-old	3-yr-old	6-yr-old	12-yr-old
Apr.	5.4	3.7	3.6	0.7	4.7	3.4	1.8
May	5.4	3.7	3.3	0.5	4.6	3.3	1.7
June	4.9	3.4	2.2 <sup>d</sup>	0.4 <sup>d</sup>	3.3 <sup>d</sup>	2.4 <sup>d</sup>	1.2 <sup>d</sup>
July	5.2	3.7	2.0 <sup>d</sup>	0.2 <sup>d</sup>	3.4 <sup>d</sup>	2.5 <sup>d</sup>	1.1 <sup>d</sup>
Aug.	3.9 <sup>d</sup>	2.9 <sup>d</sup>	2.1 <sup>d</sup>	0.4 <sup>d</sup>	3.5 <sup>d</sup>	2.6 <sup>d</sup>	1.3 <sup>d</sup>
Sep.	3.9 <sup>d</sup>	2.8 <sup>d</sup>	2.6	0.5	4.1	3.1	1.6
Oct.	4.5 <sup>d</sup>	3.2 <sup>d</sup>	2.5	0.6	4.3	3.2	1.7
Nov.	5.0	3.6	2.1	0.6	3.7	2.9	1.5
Dec.	4.9	3.6	2.3	0.7	3.8	2.9	1.6
Jan.	4.7	3.4	2.4	0.9	4.2	3.3	2.0
Feb.	4.5	3.3	2.5	1.0	4.2	3.3	2.0
Mar.	5.2	3.8	2.7	1.2	4.7	3.8	2.3
Total	57.5	41.1	30.3	7.7	48.5	36.9	19.8

<sup>a</sup> Under adequate water and nitrogen; based on LUE and LI for 8-weekly cut green panic at Redland Bay (T. Schwenke), and using incident radiation levels for Manado and Kuala Lumpur as indicated in Table 6.

<sup>b</sup> Coconuts — light transmissions 3 yr (81%), 6 yr (54%) from Wilson and Ludlow (1991). Rubber — light transmissions from Tajuddin et al. (pers. comm.) for conventional and hedgerow rubber.

<sup>c</sup> To account for non-pasture, area yields were decreased by 33% in conventional rubber and by 20% for hedgerow rubber.

<sup>d</sup> Rainfall–evaporation (R–E) for August, September and October in Manado was –26 mm, –28 mm, 2 mm (FAO 1987) and growth was reduced by 30%, 30% and 20% respectively, for these months. R–E for June, July and August at Kuala Lumpur was 19, 12 and 20 mm, respectively, and rubber yields were discounted 20% for each of these months.

month, but there is still significant variation in monthly rainfall (Table 1) which will affect pasture yield. Table 3 shows estimated yields for each month under good nutrition but with discount for water stress. In coconuts, the yields in a mature plantation are adequate to support a reasonable stocking rate, but in conventional rubber they would limit stocking at 3 years and be insufficient for animal stocking at 6 years. This is especially so in conventional rubber given that the data indicate maximum possible growth, without N restriction, pathogen or insect damage, or inedible weed invasion. Conversion to useful 'feed on offer' would also need to assume a certain percentage yield loss to account for senescence over a regrowth period, and then an adjustment (about 40%) to give leaf yield which is what animals will mostly eat. The data in Table 3 clearly suggest a marked advantage for pasture yield of the hedgerow over conventional rubber. Monthly yields would support reasonable stocking at year 6, and more restricted stocking by year 12 and thereafter.

The annual herbage yields of improved pastures under hedgerow plantings as predicted by Abd. Samat (these proceedings), were lower (maximum of 35 t/ha, declining to 26 t/ha) than the total of the monthly yields in this report, and stabilised in year 6 rather than continuing to decline from year 3 to year 12 (Table 3). In this report, hedgerow pasture yields were calculated on the basis of an area with 100% light transmission and an area under the trees of reduced light, and using the appropriate LUE or LI for the two areas. The herbage yields predicted by Abd. Samat are lower because a single light transmission value (and therefore a single UE and LI) was calculated for the entire hedgerow area. The stabilisation rather than decline of hedgerow pasture yields in Abd. Samat's model occurred because predictions of light transmission were based on extrapolations from a limited data set of tree-canopy spread in a 5-year-old hedgerow planting (Ng et al. 1979). In this report, measurements of canopy spread in 3-, 6- and 12-year-old plantations (I. Tajuddin, pers. comm.) are used.

## Conclusions

The simple model has predicted yields which tend to be higher than measured yields. The explanation may be that the LUE and LI values used were from recently established pasture which, for various reasons, will almost certainly have a higher growth rate than the same pasture when 2-3 years older. To refine the yield predictions there is a real need to obtain the LUE and LI model parameters for older pastures, especially under the 12-month growing conditions in Southeast Asia, and also to have values for the favoured species for use in plantations such as *Stenotaphrum secundatum*, *Brachiaria humidicola*

and *Arachis pintoi*. The comparison of yields shows the large advantage gained by going to hedgerow planting in rubber. The further need in the model building is to derive the necessary model parameters to convert total herbage dry matter yields to useful feed on offer and then to potential stocking rates.

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# Mechanisms of Persistence in Tropical Forages to Defoliation under Shade

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THE lack of persistence and high forage productivity in sown pastures under perennial plantation crops has been a major obstacle in the development and adoption of silvopastoral systems in Malaysia. Past experience has shown that low growing, stoloniferous grasses like *Axonopus compressus* and *Stenotaphrum secundatum* were able to persist in shade under grazing (Chen and Bong 1983; Smith and Whiteman 1985). Little is known of the mechanisms of persistence of higher-yielding sown pasture grasses when defoliated in shade. Is it simply prostrate growth habit which confers persistence or are there other factors involved? An experiment was conducted to examine the effect of 2- and 4- weekly cuttings at a 5 cm cutting height on the regrowth and persistence of two shade-tolerant grasses, a prostrate species, *Paspalum wettsteinii* and an erect species, *Paspalum malacophyllum*, grown in 100, 50 and 20% of ambient light over a 12-week period (3 cycles of 4-weekly interval). Another experiment was undertaken to evaluate the role of residual leaf area in the stubble after grazing on the regrowth and survival of the two grasses in 20 and 50% full sunlight.

## Materials and Methods

Experiment 1 was a randomised complete block in a split-split plot arrangement with 6 replications. Light levels were arranged as main plots, with defoliation frequencies as subplots while species formed the sub-subplots. Sarlon ® shade cloth was used to provide light transmission of 50 and 20% ambient light for comparison with a full sunlight control treatment.

*P. malacophyllum* and *P. wettsteinii* were established in polystyrene boxes in the open in Brisbane, Australia. All grass swards received adequate

fertilizers and water supply and were cut to a 5 cm cutting height twice before commencement of defoliation treatments.

Plants were sampled for dry matter (DM) yield and total nonstructural carbohydrates (TNC) of the leaf, stem, stubble and root components. Records of tiller number and plant mortality were taken before each harvest. At the end of the experiment, the remaining plants were transferred into a dark room for determination of etiolated regrowth potential (Burton and Jackson 1962).

Experiment 2 was a randomised complete block design in a split-split-split plot arrangement with 5 replications. Light levels were arranged as main plots with species as subplots, defoliation frequencies of 2- and 4-weekly intervals as sub-subplots and cutting heights of 5 and 10 cm formed the sub-sub-subplots. Both grasses received two cycles of defoliation as a preconditioning phase before the regrowth study of the two grasses with their stubble leaves either retained or removed at commencement of the experiment. Plant mortality was monitored over the 28-day regrowth period.

## Results and Discussion

### Total biomass production (TDM)

Both species produced similar TDM in all the treatments despite the difference in growth habit. TDM was reduced significantly ( $P < 0.01$ ) by shading in both species, the magnitude of reduction being proportional to the intensity of shade (Fig. 1). Shading reduced tiller number in both species while cutting frequency had no significant effect (Table 1).

*P. wettsteinii* produced a higher root yield while *P. malacophyllum* had a higher shoot component (Fig. 1). This differential allocation of DM resulted in higher shoot:root ratios and tiller numbers in *P. malacophyllum*, particularly with 4-weekly defoliation (Table 1). Leaf area indices and light interception were not significantly different between the two species (Table 1). Relative growth rate was generally

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**Table 1.** Summary of growth responses, TNC content and mortality of the two grasses to shade and defoliation from Experiments 1 + 2. Adapted from Wong and Stür (1993).

Light level	S:R <sup>a</sup>	SLAI <sup>b</sup>	RGR <sup>c</sup>	Till No. <sup>d</sup>	LAI <sup>e</sup>	Etiol (g/m <sup>2</sup> ) <sup>f</sup>	Mortality %	TNC (g/m <sup>2</sup> ) <sup>g</sup>
<i>P. malacophyllum</i> (erect species)								
2-weekly cut								
20%	1.0	0.15	0.07	13	1.3	4.6	6	3.4
50%	1.2	0.24	0.14	24	2.1	12.1	0	10.5
100%	1.4	0.69	0.17	41	3.4	31.0	0	33.5
4-weekly cut								
20%	2.3	0.13	0.12	14	2.2	5.7	3	11.1
50%	2.8	0.27	0.15	26	4.4	23.1	0	35.5
100%	2.6	0.62	0.23	37	5.8	37.9	0	71.9
<i>P. wettsteinii</i> (prostrate species)								
2-weekly cut								
20%	0.8	0.28	0.03	8	1.4	0.1	46	1.3
50%	0.9	0.52	0.09	14	2.4	0.2	10	4.6
100%	1.0	0.97	0.12	25	3.8	1.1	0	12.2
4-weekly cut								
20%	1.4	0.18	0.09	10	2.6	0.2	24	4.0
50%	1.6	0.14	0.12	19	4.2	1.8	8	11.9
100%	1.6	0.64	0.17	25	5.3	2.2	0	30.9

<sup>a</sup> S:R = shoot:root ratio

<sup>b</sup> SLAI = stubble leaf area index

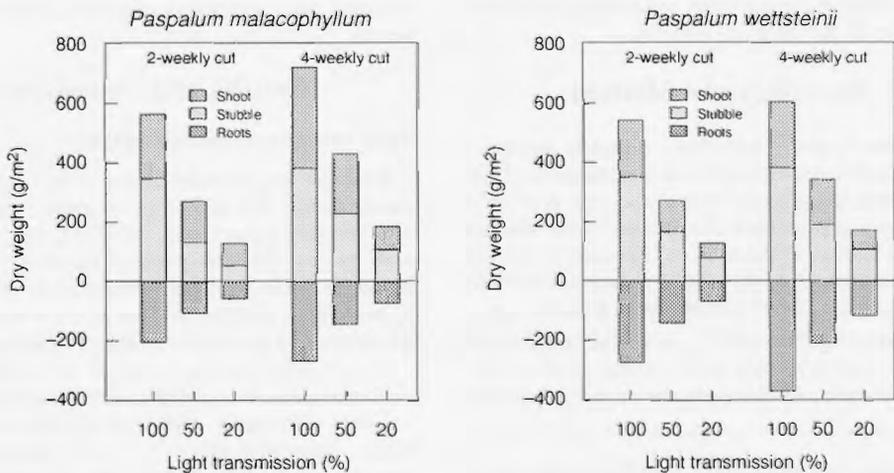
<sup>c</sup> RGR = relative growth rate (g/g/wk)

<sup>d</sup> Till no. = tiller number/plant

<sup>e</sup> LAI - leaf area index

<sup>f</sup> Etiol = etiolated regrowth

<sup>g</sup> TNC = Total nonstructural carbohydrates in stubble.



**Figure 1.** Experiment 1: Effect of shading and defoliation on root, stubble and shoot dry weight (g/m<sup>2</sup>) of *P. malacophyllum* (erect habit) and *P. wettsteinii* (prostrate habit).

higher in *P. malacophyllum* but declined with shading in both species.

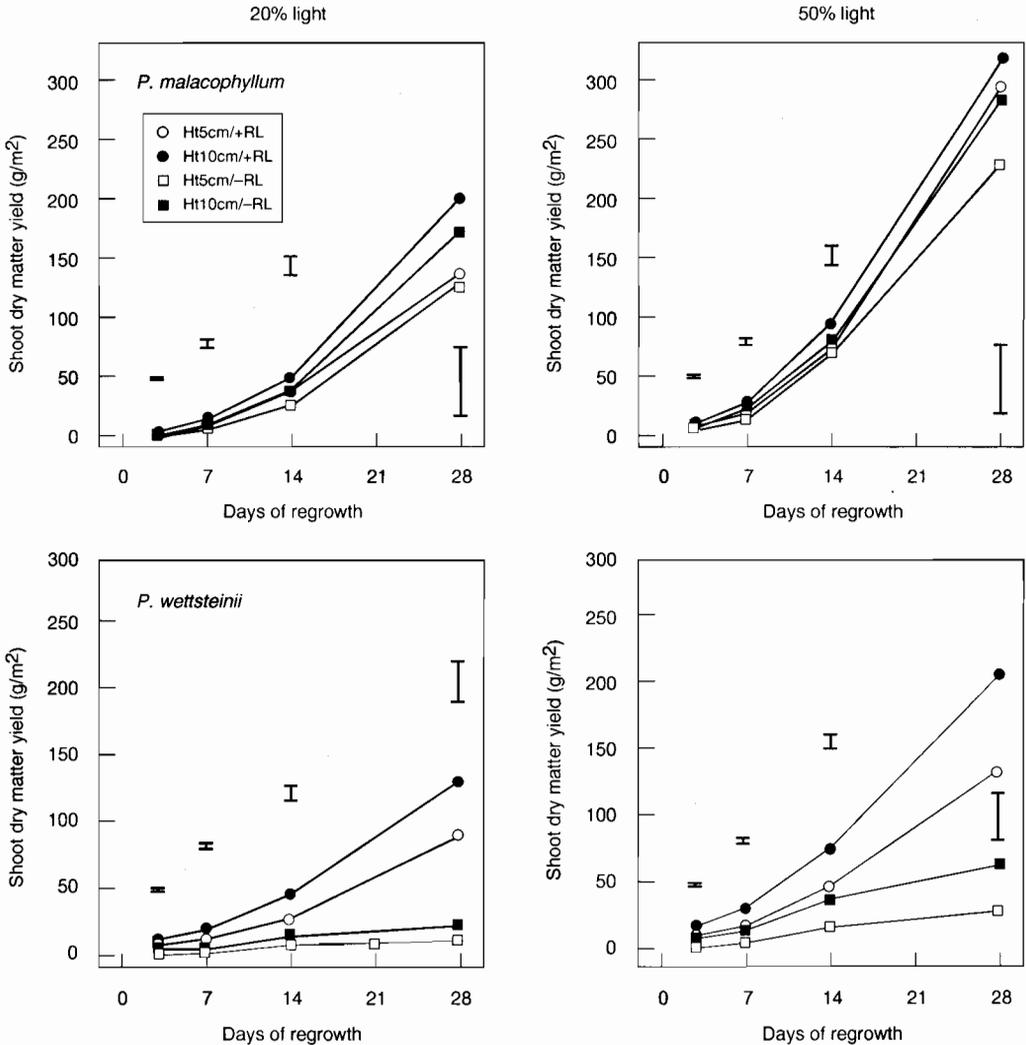
### TNC pool and etiolated regrowth

Frequent defoliation in increasing shade intensity reduced labile stubble TNC pool in both species, and increased plant mortality, particularly in *P. wettestinii* (Table 1). *P. malacophyllum* retained a higher stubble TNC and exhibited a larger amount of etiolated regrowth (Table 1). A strong correlation coefficient was obtained between the stubble TNC and etiolated

regrowth. The ability of *P. malacophyllum* to tolerate frequent defoliation in shade was attributed to its higher stubble TNC pool for regeneration.

### Stubble leaf area index (SLAI)

*P. wettestinii* had higher SLAI than *P. malacophyllum*. SLAI was higher in the 2-weekly than the 4-weekly cut swards of both species (Table 1). In Experiment 2, SLAI was also higher with higher cutting height (data not shown). Removal of stubble leaves of *P. malacophyllum* had no significant effect

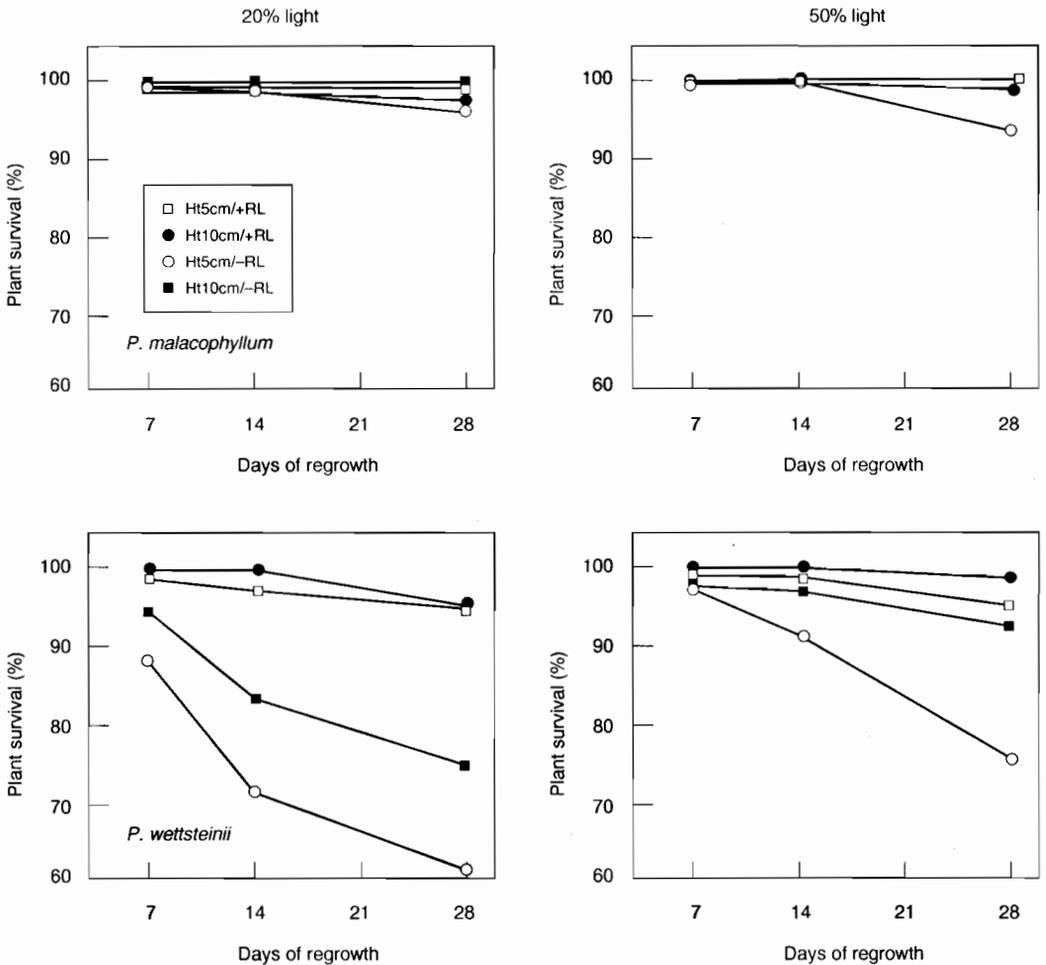


**Figure 2.** Experiment 2: Shoot dry weight (g/m<sup>2</sup>) during regrowth of *P. malacophyllum* and *P. wettestinii* in 20 and 50% light transmission, following defoliation of swards at 5 and 10 cm heights, with and without removal of residual leaves ( $\pm$ RL) of stubble. Data are means over defoliation frequencies of 2 and 4 weeks. Vertical bars indicate LSD (0.05) for interactions.

on shoot dry weight in any treatments except at days 3 and 7 after commencement of the regrowth phase (Fig. 2). By day 14, there was no effect of removal of stubble leaves on subsequent regrowth. In contrast, there was a consistently low shoot dry weight of *P. wettsteinii* upon removal of stubble leaves irrespective of cutting height (Fig. 2). This poor shoot growth resulted in a higher mortality of this grass under dense shade (Fig. 3). The ability of *P. malacophyllum* to restore its shoot regrowth early appeared to be a contributory factor to its higher persistence because of high stubble TNC levels.

The experiments demonstrated the contrasting responses of the two *Paspalum* grasses to defoliation management in shade. The prostrate *P. wettsteinii* relied on the stubble leaves for its survival because of

its low tiller production, slow shoot regrowth, low reserves of TNC in the stubble, and a preferential DM allocation to root biomass. On the other hand, *P. malacophyllum* allocated its organic reserves into greater tiller production and development. This resulted in a higher shoot regrowth than *P. wettsteinii*. However, at the same time *P. malacophyllum* also allocated a reasonable proportion of photosynthate to stubble reserves of TNC. This reserve, although greatly diminished under shade, was still sufficient to support reasonable regrowth after defoliation (as evidenced by the etiolated shoot response). Such a response may have mitigated the importance of stubble leaves for initial shoot regeneration. The ability to store TNC and regenerate photosynthetic surface rapidly was an important adaptive feature for growth and



**Figure 3.** Experiment 2: Plant mortality (% of original plant population) of *P. malacophyllum* and *P. wettsteinii* in 20 and 50% light transmission at day 28 following defoliation at two cutting heights (5 and 10 cm) and two cutting intervals (2 and 4 weeks) with and without removal of residual leaves of stubble at day 0.

persistence in shade. Without TNC accumulation, *P. wettsteinii* had very poor survival when stubble leaves were removed. These experiments used artificial cutting and it is evident that under grazing the capacity of stubble leaves to escape removal will be very important.

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# Nitrogen Availability and Grass Yield under Shade Environments

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NITROGEN availability is a major determinant of grass yield in all pasture systems throughout the tropics and subtropics. In few instances is it economic to supply fertilizer N for pasture production. Consequently, grass pastures depend on high natural soil fertility and a rapid mineralisation of N from soil organic matter to sustain good productivity. In many areas of Southeast Asia and Australia, one or other, or both, of these attributes are at the lower end of the scale and pasture growth is severely N limited. Even when soils are naturally fertile, such as the young volcanic soils in Bali, frequent harvesting of plant material from plots as reported in Shelton and Stür (1991), or cut-and-carry systems of animal feeding, will create N-limited situations. For example, a 300 kg stall-fed animal consuming 7.5 kg dry matter/day at 1.5% N will remove 41 kg N/year, and with a hectare supplying feed for perhaps three head then N removal could be 120 kg N/ha/yr. N cycling through organic matter breakdown, legume input, or dung and urine return, would need to be high to replace this loss. In Australia, even fertile soils with animals grazing in-situ, consuming as little as 20% of pasture dry matter and with 80% of this consumed N returned as urine and dung, will suffer severe N rundown problems limiting pasture growth (Myers and Robbins 1991). In this instance, uneaten dry matter is returned to the soil as poor quality litter with high carbon:nitrogen ratio resulting in very slow organic matter breakdown and low N mineralisation (Robertson et al. 1994).

Higher N availability in soils under artificial- and tree-shaded environments has been reported for a number of situations, e.g. in Australia (Wilson et al. 1986, Wilson and Wild 1991), East Africa (Belsky et al. 1993), the Mediterranean (Joffre et al. 1988) and the Caribbean (Cruz et al. 1993). These reports seem to be generally associated with water-restricted envi-

ronments. This paper presents some recent information on shade effects on N availability and pasture yield from ACIAR and complementary CSIRO projects. The data are evaluated to gain understanding of the reasons for increased soil N availability under shade which sometimes leads to higher pasture yield under shade than in full sunlight.

## The 'Shade Effect' on Dry Matter and Nitrogen Yield

The 'shade effect', viz. greater herbage growth of sun-tolerant pasture grasses under shade than in full sun in N-limited situations, e.g. under tree canopies (Lowry et al. 1988, Weltzin and Coughenour 1990, Wilson et al. 1990), is of some significance to plantation or agroforestry systems. It may be seen clearly in results from two experiments conducted in southeast Queensland (Table 1). The positive responses in grass herbage yield for shade compared to full sunlight treatments were large. In a humid coastal environment at Samford they were +124% for artificial 50% shade and +41% under a 10-year-old plantation of eucalypts, and in a sub-humid, dry inland environment at Narayen it was +39% under 50% artificial shade. Proportional increases in N yield (Table 1) were of the same order. The increased N yield of tops cannot be fully explained by reallocation of N from a smaller root system in response to the imposition of artificial shade at either Samford or Narayen (Table 1); this agrees with the earlier conclusion of Wilson et al. (1986). The difference in N content of grass roots under trees (Table 1) compared to full sun (-69 kg N/ha) could numerically explain the extra gain in N in grass tops under trees (+22 kg N/ha). However, the plantation/pasture system was 10 years old and the adjustment to a smaller root system for the grass (in dry matter and N yield) occurred well before the start of this experiment. Therefore, the smaller root system does not necessarily indicate extra N available for reallocation to 'current' growth of tops, as is the case for the artificial shade treatment (Table 1) where a previous area of 'sun' pasture was suddenly shaded

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causing shrinkage of the existing root system. The significance of an improvement in soil N availability could be enhanced in pasture mixtures by the fact that nodulation and N fixation for legumes is often reduced under shade (Lie 1974) and thus they may not be such effective providers of symbiotically-fixed N for grass growth as they are in full sun pastures. Wong and Wilson (1980) found that siratro (*Macroptilium atropurpureum*) under shade had severely reduced nodulation and N yield and was less competitive with the accompanying grass. However, the opposite response of higher relative yield of legume compared to grass under shade than in full sun was reported for mixtures of centro/guinea and centro/signal (Sophanodora 1991), and *Arachis pintoii*/*Paspalum notatum* (T. Schwenke, pers. comm.). The influence of shade on nodulation and N fixation of shade-tolerant legumes under plantations and their contribution to associated grass needs to be ascertained.

Physiologically, the 'shade effect' on grasses can be explained by the gain in net photosynthesis (through higher leaf N%) being greater than the loss in potential photosynthetic activity when light level decreases by up to around 50% (Wilson and Wild 1991). This is only relevant where N is significantly limiting, because under N deficiency the photosynthetic light-response curve is saturated with only 50% light (Wilson 1975). The effect is unlikely to be seen at light levels much lower than 40–50% because photosynthetic rate then drops steeply and increasing plant N concentration cannot give sufficient compensation to maintain net carbon intake equivalent to full sunlight conditions.

Significantly, there is no 'shade effect' on grass yield in solution culture at either high or low N supply (Wild et al. 1993). This result strengthens our belief that the 'shade effect' is soil-related and that the gain in N and grass growth under shade largely results from faster organic matter breakdown and greater N mineralisation. Further support is added by the lower litter yields (despite greater tops growth) and faster litter decomposition under shade seen in experiments with bahia grass (*Paspalum notatum*) pastures at Samford (Table 2). However, the possibility that the 'shade effect' is not an N availability response but simply arises from less evapotranspiration, and thus less water stress for plant growth, should be examined.

**Table 2.** Influence of shade environment on litter breakdown on bahia grass pastures at Samford, southeast Queensland<sup>a</sup>.

	Litter yield on plots <sup>b</sup> (t/ha)	Litter loss from surface bags <sup>c</sup> (% of starting weight)
Full sunlight	5.1	-26.7
Under trees	4.4	-26.3
Artificial shade	3.3 <sup>d</sup>	-37.6 <sup>d</sup>

<sup>a</sup> Description as in Table 1.

<sup>b</sup> Litter on plots at end of 18-month experiment.

<sup>c</sup> Dead leaf litter collected from artificial shade plots of bahia grass and placed in nylon mesh bags on the soil surface of each treatment; weight loss recorded after 3 months during early summer.

<sup>d</sup> P < 0.01

**Table 1.** Influence of shade environment on cumulative dry weight and nitrogen yield for plant tops and roots of bahia grass and green panic pastures in southeast Queensland (Relative difference in brackets).

	Samford—Bahia grass <sup>a</sup>		Narayan—Green panic <sup>b</sup>			
	DM yield (t/ha)	N yield (kg/ha)	DM yield (t/ha)		N yield (kg/ha)	
			Irrigated	Dryland	Irrigated	Dryland
<b>Plant tops</b>						
Full sunlight	5.8	58.9	12.2	8.5	109	87
Under trees <sup>c</sup>	8.2 <sup>f</sup> (+41%)	80.6 <sup>f</sup> (+37%)				
Artificial shade <sup>d</sup>	13.0 <sup>f</sup> (+124%)	128.2 <sup>f</sup> (+118%)	16.9 <sup>f</sup> (+39%)	12.2 <sup>f</sup> (+42%)	162 (+49%)	117 (+34%)
<b>Roots<sup>e</sup></b>						
Full sunlight	46.5	237.0	16.5	13.0	336	270
Under trees <sup>c</sup>	22.2 <sup>f</sup>	168.0 <sup>f</sup>				
Artificial shade <sup>d</sup>	30.9	203.00	12.8	14.3	278	300

<sup>a</sup> *Paspalum notatum* pastures—three harvests over two growing seasons, 8 replications, humid coastal environment.

<sup>b</sup> *Panicum maximum* var. *trichoglume*, 7 harvests over 2 years, 3 replications, sub-humid inland environment.

<sup>c</sup> *Eucalyptus grandis* at 6.5 m × 6.5 m (237 trees/ha), shade level 45–65%

<sup>d</sup> Sarlon shade cloth 50% transmission.

<sup>e</sup> Roots 0–40cm depth (Samford) and 0–30 cm depth (Narayan).

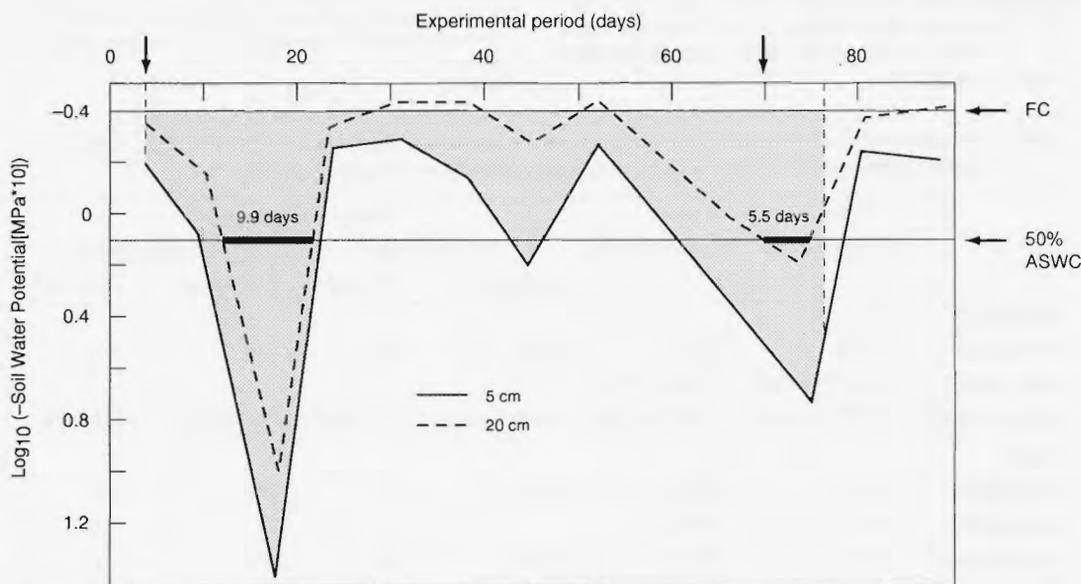
<sup>f</sup> P < 0.01

## Possible Role of Reduced Plant Water Stress Under Shade

A procedure is detailed here to enable assessment of the extent of reduced water stress for plant growth under shade compared to full sun. Wilson and Wild (1991) showed that in a dry environment at Narayan, southeast Qld, 50% artificial shade greatly reduced the rate of soil drying compared to the full sun control. In subsequent work we have attempted to quantify the stress days for plant growth experienced by the sun and shade treatments. This has been done by installing gypsum blocks at various soil depths and reading them at frequent intervals, an example of such data for a sun treatment is given in Figure 1. Stress days are then calculated based on soil water potential (SWP) at 20 cm depth which is regarded as within the main root zone for grass. Plant growth reduction is defined as occurring when available soil water content (ASWC) at this depth has declined below 50% (Mc Cown 1973). For both the two main soil types at Narayan, the soil moisture characteristic curves indicate that the SWP equivalent to 50% ASWC is  $-1.3$  bars ( $0.13$  MPa). Hence, in Figure 1, days when SWP is below  $-1.3$  bars ( $= 0.11$  [-log units]) are regarded as stress days. They may be summed over the regrowth periods being examined. (N.B. a log plot of SWP as in Figure 1 is not neces-

sary for this purpose but is presented as such for the microbial activity calculations described below).

Using the stress day analysis, artificial shading clearly reduced the number of water stress days for plant growth (Table 3). The effect was large at Samford, a 46% decrease in a very dry year 1991, and a 23% decrease at Narayan, in the moderately dry years 1989 and 1990. This could suggest that the yield gains under shade result from less water stress for plant growth. However, the bahia grass pasture under trees at Samford was just as water-stressed as under full sun yet gave a 41% higher yield (Table 1). In addition, at Narayan, irrigated, shaded *Panicum maximum* var. *trichoglume* (green panic) had only about one-third as many water stress days as dryland, shaded green panic yet both treatments gave a similar proportional increase in yield (39 and 42%, Table 1) as a shade response. Also, in the irrigated plots, the +39% 'shade effect' occurred despite there being virtually no difference in stress time between sun and shade treatment (Table 3). The evidence from the current experiments for the 'shade effect' being largely due to reduced water stress for plant growth is thus slight. This conclusion is supported in detailed analysis by Belsky et al. (1993) of 'shade effects' on pasture yield under isolated tree canopies of acacia and baobab at African sites of low (750 mm,  $\equiv$  Narayan) to very low (450 mm) annual rainfall. They



**Figure 1.** A data set for a *P. maximum* var. *trichoglume* sun plot from the Narayan site showing soil water potential (SWP plotted as log values) for gypsum blocks at 5 cm (solid line) and 20 cm (dashed line) depths for a 90-day period: line at  $-0.4$  indicates fully wet soil (near field capacity, FC), and at  $-0.11$  indicates 50% available soil water content (ASWC) for this soil. Heavy lines = periods below 50% ASWC at 20 cm depth and hatched area = integrated water stress for microbial activity (5 cm depth) over a given harvest period ( $\downarrow$ ).

**Table 3.** Comparative effect of sun and shade treatment on soil water deficit<sup>a</sup> as it might influence plant growth or relative microbial activity (N mineralisation) at Samford and Narayen sites, southeast Queensland<sup>b</sup> (Relative differences in brackets).

	Samford —Bahia grass		Narayen —Green panic			
	Stress days for plant growth <sup>c</sup> (% of total days)	Relative microbial activity stress <sup>d</sup> (log MPa days)	Stress days for plant growth <sup>c</sup> (% of total days)		Relative microbial activity stress <sup>d</sup> (log MPa days)	
			Irrigated	Dryland	Irrigated	Dryland
Full sunlight	68	150	13.9	50.1	314	431
Under trees <sup>b</sup>	69 (0%)	165 (+10%)				
Artificial shade <sup>b</sup>	37 (-46%)	118 (-21%)	12.2 (-12%)	38.3 (-23%)	147 (-53%)	313 (-27%)

<sup>a</sup> Measured by gypsum blocks.

<sup>b</sup> Details as described in Table 1.

<sup>c</sup> Numbers of days when soil water potential at 20 cm depth was < - 0.13 MPa (= to 50% available soil water content from soil moisture characteristic curve) expressed as percentage of total number of days over which yield was measured in 1991 (Samford) and 1989–90 (Narayen).

<sup>d</sup> Based on linear relationship of microbial activity (N mineralisation) to log soil water potential; data as integrated area under curve of log MPa soil water against time (with base line equivalent to log MPa of fully wet gypsum block, see Fig. 1). Higher values indicate greater stress for microbial activity.

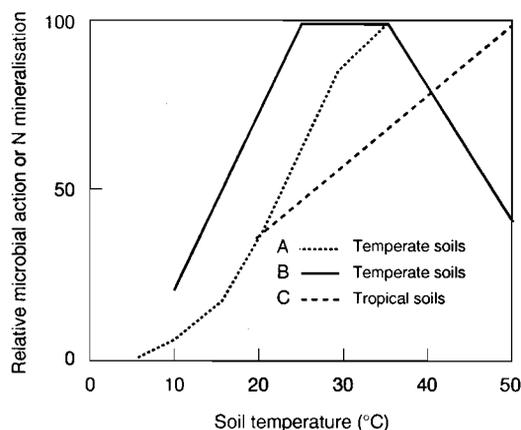
found yield increases respectively of +52 and +95% for tree understory herbage compared to full sun herbage but, on a yearly basis, no difference in soil moisture between tree and open pasture sites. Although to be even-handed, in certain agroforestry systems, there may be circumstances where, in the surface soil layers, root competition between tree and understory grass leads to excessive water stress contributing to reduced herbaceous growth. Eastham et al. (1990) had evidence of this at very high tree densities (2150 stems/ha) in a *Eucalyptus grandis*/ *Setaria sphacelata* tree/grass combination.

### Shade Benefits for Enhanced Microbial Activity and N Mineralisation

Belsky et al. (1993) provided clear evidence for higher soil N availability and higher microbial biomass under trees, and some evidence for faster N mineralisation; i.e. more active biological N cycling. Shade ameliorates the soil surface temperature and water environment and the implications of these effects for increased microbial activity, and thus higher N mineralisation, warrant quantitative analysis.

Three relationships (Fig. 2) all show microbial activity increasing with soil temperature to at least 35°C, but relationship B (from temperate soils) indicates an optimum at that temperature, whilst relationship C (from tropical soils) indicates microbial activity increasing linearly to 50°C. This difference perhaps indicates a different population of microbial species adapted to low (temperate) and high (tropical) soil temperatures. In the absence of further evi-

dence the latter trend must be regarded as appropriate to our experimental areas. Therefore, the lower temperatures under the litter layer and in surface soil under shade (Table 4) appear unlikely to benefit litter breakdown, in fact should slow it in relation to full sun. Except perhaps, on those occasions in summer when soil surface/litter temperatures in sun exceed 50°C as can happen at both Australian sites (Table 4); and on these occasions the litter in full sun will also be very dry.



**Figure 2.** Relationship between relative microbial activity or N mineralisation and soil temperature for temperate region soils (A) Kladiivko and Keeney 1987 and (B) van Veen and Frissel 1981, and tropical region soils (C) Myers 1974.

Microbial activity and N mineralisation decline linearly with decline in soil water content below field capacity, and hence also linearly with decline

**Table 4.** Influence of shade environment on daily maximum temperatures (°C) of pasture canopy, under litter and in surface soil at Samford and Narayen sites, southeast Queensland<sup>a</sup>.

	Samford—Bahia grass <sup>b</sup>			Narayen—Green panic <sup>c</sup>		
	Litter (°C)	2.5 cm soil (°C)	Canopy (°C)	Litter (°C)	2 cm soil (°C)	5 cm soil (°C)
Full sunlight	57.9	34.8	33.5	41.4	40.2 (52)	34.6
Under trees <sup>a</sup>	45.6	31.7				
Artificial shade <sup>a</sup>	35.4	30.1	32.4	31.8 <sup>d</sup>	30.8 <sup>d</sup> (35)	27.4 <sup>d</sup>

<sup>a</sup> Details as described in Table 1.

<sup>b</sup> Hot, sunny day (27 December).

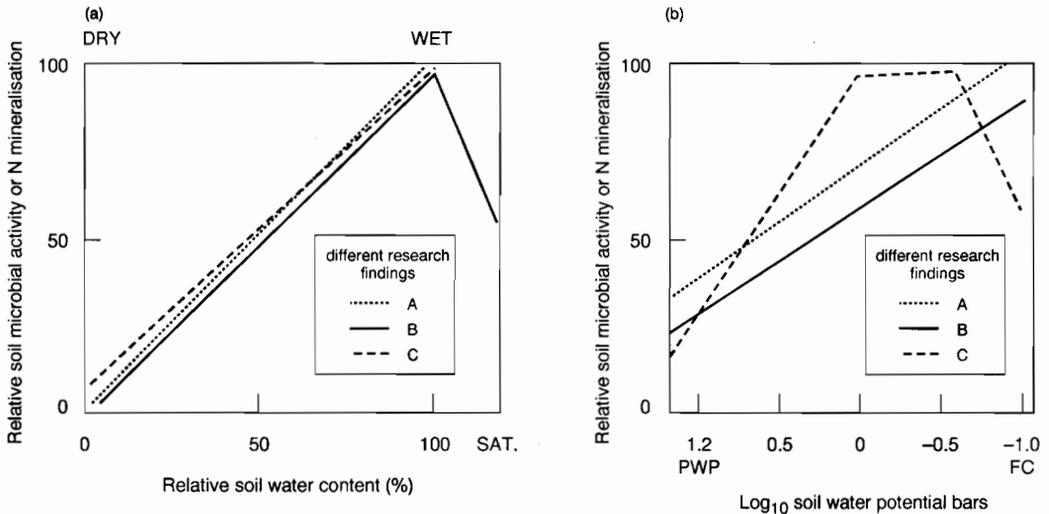
<sup>c</sup> Averages for period 7–17 March, data in parentheses are for an individual hot day (18 January).

<sup>d</sup>  $P < 0.01$

in log SWP (Fig. 3). Several of the relationships suggest an optimum water content, beyond which microbial activity declines sharply as soils become saturated; relationship C (Fig 3b) suggests an optimum lower than field capacity, but this probably reflects difficulty of translating data from the curve in the original publication (Kladivko and Keeney 1987). Periods above field capacity are rare for Australian experimental sites but may be of significance in the high rainfall, wet tropics of Indonesia and Malaysia, and other countries of Southeast Asia. To quantify the influence of soil dryness on microbial activity, we assumed that the surface soil was most important, and hence analysed gypsum block data for 5 cm depth at Narayen and Samford (gypsum

blocks are not very satisfactory for shallower depths than 5cm). Soil water potential as  $-(\log \text{ bars} = \log \text{ MPa} \times 10)$  was plotted over time for these depths, see example for Narayen (Fig. 1). Then, assuming a baseline equivalent to a fully wet (field capacity) gypsum block, viz.  $-0.4$  bars at Narayen ( $= -0.4$  in the  $-\log$  units), the area under the soil water potential curve was integrated (Fig. 1) to give a relative stress measure as log bar days. These are converted to correct SI units, viz. log MPa days (Table 3); higher values indicating greater reduction in microbial activity/N mineralisation.

Stress on microbial activity due to surface soil dryness at Samford and Narayen was reduced under artificial shade by around 21 and 27% respectively



**Figure 3.** Relationship between relative microbial activity or N mineralisation and (a) relative soil water content (%)—(A) Kladivko and Keeney 1987, (B) Godwin and Jones 1991, (C) Campbell et al. 1981; and (b) log soil water potential—(A) Kladivko and Keeney 1987, (B) Orchard and Cook 1983, (C) van Veen and Frissel 1981. [SAT = saturation, PWP = permanent wilting point, FC = field capacity].

compared to full sun (Table 3), but under trees was slightly higher than in full sun. This aspect of shade in conserving moisture in the surface layers helps explain faster litter breakdown (Table 2), more N and more growth (Table 1) under artificial shade. However, under trees surface soil dryness was similar to that for full sun. Shade may have reduced soil temperatures and evaporative loss but this positive benefit must have been offset by higher water use by the combined tree-pasture canopy. The explanation of the pasture dry matter and N yield increase under tree shade has thus not been helped by this analysis.

### Shade Effects on Earthworms

Earthworms are known to contribute strongly to turnover of soil organic matter and improve soil fertility. An assessment of earthworms was made on one occasion for the Samford and Narayen sites (Table 5). These data showed an increase in population under artificial shade compared to full sun, and a large population under the eucalypt trees. Introduction of earthworms into soil cores of tropical grass in pots has increased N availability and stimulated grass growth in glasshouse experiments (Blakemore 1993). The amelioration of the soil water and temperature environment under artificial shade appears to benefit earthworm populations. Under trees, maybe the effect is largely due to cooler soil temperatures, especially during summer. Perhaps earthworms are contributing importantly to increased N availability? More work is needed to quantify this effect, which could be large in longer term shade environments, such as under tree plantations, where earthworms (and other soil mesofauna) can build up with time.

### General Discussion and Conclusions

Under tree canopies, higher soil fertility and greater N uptake in understorey herbage have been consistently demonstrated over a range of ecological circumstances outside the wet tropics. This gain in fertility is often ascribed to tree factors such as tree litter fall, bird droppings, camping animals, etc. (e.g. Weltzin

and Coughenour 1990). However, the current studies show that under shade-cloth the gains in N and grass yield are greater than for pasture under trees, and thus demonstrate quite conclusively that the shade environment per se is the critical factor leading to a 'shade effect'. The effect does not appear to result from reducing water stress for plant growth, as: (1) irrigating shade and sun plots at Narayen virtually eliminated water stress for plant growth but still gave a strong shade response; (2) tree plots at Samford were as dry as the sun plots but showed a yield response of +41%. Microbial activity for N mineralisation should have been favoured by the better water status in surface soil layers under artificial shade, this was particularly so for the irrigated plots at Narayen (Table 3), and N uptake under shade (162 kg/ha) was much higher than in sun (117 kg/ha). Again, however, this does not explain the 'shade effect' under the tree plots at Samford because there the surface soil was as dry or drier than in full sun. Earthworm populations under the trees were high and this probably indicates a more benign soil environment for biological activity (and N cycling?). Of course, if temperature response curves for microbial activity showed an optimum of around 32°C, and non-activity to 50°C, then a benefit of shade would clearly be reduced soil surface temperatures. More experiments are needed to confirm the Myers (1974) relation shown in Figure 2.

We believe that the main sun and shade differences in activity for organic matter breakdown and N mineralisation reside in just the top few centimetres of the soil and litter layer. Consequently, our ability to make a clear link between the 'shade effect' and the soil environment under shade is limited because current measurements at soil depths of 5 cm or deeper, and on a weekly (not continuous) time scale, are perhaps not sufficient to show the full benefit of shading (tree or artificial) for stimulating biological activity in the surface zone. Controlled experiments are needed to test this hypothesis.

It should be stressed that the 'shade effect', i.e. one giving not just higher N availability, but higher grass yield under shade than in sun, will only occur in special circumstances. It will not occur: (a) when N sup-

Table 5. Effect of shade environment<sup>a</sup> on earthworm population and mass<sup>b</sup>.

	Samford		Narayen			
	Bahia grass		Green panic		Rhodes grass	
	Number/m <sup>2</sup>	Mass (kg/ha)	Number/m <sup>2</sup>	Mass (kg/ha)	Number/m <sup>2</sup>	Mass (kg/ha)
Full sunlight	0	0	8	2	3	2
Under trees	200	108				
Artificial shade	48	56	137	40	27	15

<sup>a</sup> Treatments as described in Table 1.

<sup>b</sup> R.J. Blakemore, D.M. Wild and J.R. Wilson (unpublished data).

ply is adequate because of fertilizer addition; (b) with new pasture sowings when cultivation initially releases large amounts of N (Robertson et al. 1994); (c) if tree densities are high and thus light levels too low, e.g. 12-15% (Robinson 1991) or water competition too high (Eastham et al. 1990); (d) if the grass species is not a forest-margin or shade tolerant type, e.g. buffel or spear grass (J.R. Wilson, unpublished data); (e) if nutrients other than N are severely deficient or (f) if the normal (non-shaded) environmental conditions already favour maximum rates of organic matter breakdown and N cycling.

In many regions of the wet tropics in Southeast Asia, with frequent cloud and rain, air and soil surface temperatures and soil water status are perhaps always near optimum for microbial activity, litter breakdown and N mineralisation, so a 'shade effect' on yield in drier environments in Australia and Africa (Belsky et al. 1993) may not often occur.

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# **Animal Production**

# Cattle Production from Grazed Pastures in North Sulawesi

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NORTH Sulawesi is one of the major coconut producing regions in Indonesia. Cattle graze predominantly naturalised grasses and weeds under coconut plantations. Land use pressure is relatively low and the coconut understorey is currently underutilised. About 200 000 ha of coconut plantations in North Sulawesi are suited to upgrading with improved pastures.

New markets for beef cattle have opened with the construction of the live cattle export facility at Lolak (250 km south of Manado). With steadily increasing beef prices, the future for the fledgling beef cattle industry is bright. A major limitation to the industry's development is the poor continuity and low liveweight gains from the naturalised pastures that form the basic feed for cattle. 'Best-bet' improved forage species suitable for grazing under coconuts were suggested by Kaligis and Sumolang (1991). Three grass-legume pasture mixtures were selected from these best-bet species and evaluated for stability and animal production potential under continuous grazing. This paper reports the interim results from this grazing trial.

## Materials and Methods

The trial was sited on the privately owned Amalia Estate, Lolak, south of Manado. Edaphoclimatic information is reported by Kaligis and Sumolang (1991).

### Treatments and experimental design

Cattle liveweight gain and pasture stability in terms of persistence, grass-legume balance and weed invasion were assessed for one naturalised and three improved pasture treatments under mature coconuts (10 × 10 m spacings, 70% estimated light transmission).

Treatment areas of 1 ha each were established in February 1992 (Table 1). Individual cattle within treatments were regarded as replications. A core stocking rate of 3 head/treatment was maintained throughout the experiment.

### Pasture establishment

Improved pasture paddocks were prepared by spraying existing vegetation with glyphosate (360g/L) at 1 L/ha. Dead material was removed before ploughing and harrowing. *Paspalum notatum* and *Brachiaria decumbens* were established from seed at 5 kg/ha. Legumes were sown in alternate rows 25 cm apart at 5 and 15 kg/ha for *Centrosema pubescens* (centro) and *Arachis pintoii* cv. Amarillo respectively.

Fifty kg/ha potassium (K) was applied (as muriate of potash) during establishment and another 50 kg/ha K and 20 kg/ha phosphorus (as superphosphate) was applied at the start of grazing to address nutrient deficiencies indicated by soil analysis.

During the establishment period, the plots were weeded to remove unsown species. Subsequent weeding was performed periodically and the time taken to weed each treatment was recorded.

### Grazing

Grazing commenced in January 1993 when all pastures were well established. Stocking rate was adjusted for each treatment to maintain a sward height of 5–10 cm for the high stocking pressure treatments (1, 2 and 3) and 10–15 cm for treatment 4. A core of 3 head/ha was maintained in all treatments throughout the experiment.

### Cattle

Local Brahmin/Ongole crossbred cattle were vaccinated with 6-in-1 vaccine and drenched to control intestinal parasites every six months. All cattle had access to water and salt-based mineral blocks.

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## Measurements

The liveweights of cattle were recorded monthly. Estimates of presentation yield and botanical composition were performed using the Botanal technique (Tohill et al. 1992) at the start of the experiment and then every three months.

## Results and Discussion

Individual liveweight gains were comparable to those cited in the literature (Smith and Whiteman 1983; Reynolds 1988) for all treatments (Table 1). High stocking rates were sustained throughout the experiment and this no doubt contributed to the relatively low liveweight gains achieved. The genetic potential of the crossbred cattle used was unknown but may also have limited liveweight gain.

The *Brachiaria decumbens* cv. Basilisk (signal grass) treatment established rapidly from seed to produce a vigorous, weed-free pasture. A reasonable legume component (> 10%) was maintained with centro establishing very well initially. With grazing, the contribution to DM of centro declined whereas that of Amarillo increased. Amarillo grew well where the signal grass sward had thinned from heavy grazing and under patches of weeds. Together with the naturalised legumes *Mimosa pudica* and *Desmodium heterocarpon*, these legumes maintained a satisfactory legume component (Table 1).

The signal grass treatment produced the highest cattle liveweight gains (LWG) over the 18-month period (Table 1), although LWGs were not as high as for similar pastures elsewhere (Macfarlane et al. 1994). Factors limiting high LWGs in this trial included the high stocking rate (4.2 head/ha) and the low rainfall experienced in 1994. *Cassia tora* steadily invaded the pasture along with a range of other weed species, including *Stachytarpheta urticifolia* and *Sida urens*. It was apparent that at this high stocking rate the pasture would soon succumb to weed invasion (Table 1).

The vegetatively planted *Stenotaphrum secundatum* (buffalo grass) established a complete, weed-free cover very rapidly. Amarillo established well initially, however grazing of this treatment was delayed while other treatments were establishing and much of the Amarillo failed to persist in the vigorous grass sward. At the commencement of grazing the legume content was negligible (Table 1).

LWGs from the buffalo grass treatment were acceptable in year 1 but poor in year 2 (Table 1). The pasture maintained a weed free sward at a high stocking rate (3.8 head/ha). Similar results were reported by B.F. Mullen and H.M. Shelton (unpublished data) and it was suggested that acceptable cattle LWGs would only be achieved at low stocking rates or in combination with persistent high quality legumes.

*Paspalum notatum* established poorly from seed and spread very slowly. The naturalised *Axonopus compressus* dominated the grass fraction of this treatment during year 1. Amarillo and centro established vigorously and this treatment became legume dominated. LWGs were similar to those achieved from buffalo grass (Table 1). However, weed invasion, dominated by *C. tora*, increased dramatically in year 2. *P. notatum* established in patches and these patches formed a weed free sward that resisted legume association. Amarillo persisted well even as the pasture became more weed infested.

The native pasture control treatment maintained a very high legume content of naturalised legumes initially, including *C. pubescens*, *Pueraria phaseoloides*, *M. pudica* and *D. heterocarpon*. The *A. compressus* grass component was not vigorous and was quickly over-run firstly by legumes and then by weeds. Liveweight gains were superior to buffalo grass LWGs in year 1 but as the legume content dropped and as unpalatable weeds began to dominate the pasture in year 2, LWGs declined substantially. *C. tora* was again the dominant weed in this treatment.

Table 1. Liveweight gains from and botanical composition of grazed pasture treatments in North Sulawesi.

Treatment	Liveweight gain (kg/head/day)	Botanical composition					
		Legume content (%)			Weed content (%)		
		July 93	May 94	Sept. 94	July 93	May 94	Sept. 94
1. Naturalised pasture	0.30	20	20	10	60	75	80
2. <i>Paspalum notatum</i> cv. Competidor + legumes <sup>a</sup>	0.35	25	25	18	25	50	50
3. <i>Stenotaphrum secundatum</i> Vanuatu + legumes	0.25	2	3	3	0	4	5
4. <i>Brachiaria decumbens</i> cv. Basilisk + legumes	0.42	30	11	15	5	10	25

<sup>a</sup> *Arachis pintoi* cv. Amarillo + *Centrosema pubescens*.

## Conclusions

LWGs from the signal grass treatment were superior to other treatments, however the treatment was becoming increasingly weed infested at the high stocking rate used. *P. notatum* established poorly from seed and although LWGs were initially satisfactory, the pasture had succumbed to severe weed invasion. LWGs from the native pasture control were initially satisfactory but declined dramatically as the treatment became weed infested. Only the buffalo grass pasture maintained a weed free sward. Unfortunately LWGs were poor as legumes failed to persist. The introduction of a tree legume component, such as *Leucaena leucocephala*, may successfully add nutritive quality to the stable buffalo grass sward and produce the higher LWGs required by the market. Alternatively, careful management of signal grass-legume pastures would also provide satisfactory LWGs.

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# Pasture Establishment and Grazing Management in Bali: Observations from the Pulukan Grazing Trial

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IN 1992, a cattle grazing trial was set up at the Bali Cattle Genetic Improvement Project, Pulukan, Bali. The trial aims were to assess the productivity of cattle grazing native and 'best-bet' sown pastures under coconuts and to evaluate the performance of these pastures for persistence, grass-legume balance and susceptibility to weed invasion. Poor control over livestock management caused the trial to be terminated prematurely. However, important information regarding pasture establishment and the tolerance of pasture species to heavy grazing pressure was recorded, together with some preliminary animal production data. This information is presented in this paper.

## Pasture Establishment

Four pasture treatments, including three sown treatments and a native pasture control (Table 1), were planted in January 1992. Seeded species, *Paspalum notatum* and *Arachis pintoii* cv. Amarillo, had to be resown in March because of poor establishment related to low seed quality. Ground preparation had been thorough and soil moisture was adequate at planting. Seed of Amarillo is fragile, and loses viability rapidly under poor storage conditions (B.F. Mullen, pers. comm.). Poor establishment of *P. notatum* was also found in Malaysia (T. Ismail, pers. comm.) and in North Sulawesi (Kaligis and Sumolang, these proceedings). Both species were replanted from vegetative material and established well. *P. notatum* spread very slowly however.

*Stenotaphrum secundatum* (buffalo grass) established well from cuttings and spread rapidly. Ideally buffalo grass cuttings should be planted in a 1 m × 1 m grid pattern, however, insufficient planting mate-

rial was available and the spacing had to be widened to approximately 1.5 m. This factor, in combination with poor control over grazing by cattle prevented the buffalo grass from forming a full cover. The Floratam cultivar was also found to be slower to spread in comparison with the Vanuatu ecotype.

*Calliandra calothyrsus* established well from seedlings and grew to an average height of 2.3 m 13 months after planting. A density of 800 stems/ha were established.

## Initial Animal Production

Animal production was recorded over the first four months of the trial. All paddocks were stocked with 3 head/ha Bali cattle (*Bos banteng*). The calliandra treatment proved to be the most productive with average daily gains of 0.33 kg/hd. Buffalo grass, *P. notatum* and native pasture treatments produced average daily gains of 0.3, 0.29 and 0.16 kg/hd/day respectively.

## Persistence Under Heavy Grazing

As stock control deteriorated, the pastures became increasingly heavily grazed. Calliandra proved to be totally intolerant of this treatment and within two years of the commencement of the trial every plant was dead. As cattle grazed, layers of bark and cambium were stripped down the stem (Fig. 1). Though never more than 50% of bark was removed, trees died in the following months. It is unlikely that *Leucaena leucocephala* subjected to a similar treatment would have experienced such mortality, considering that the plants were thoroughly established with an average height of 2.3 m. Partial mortality of calliandra was also reported in North Sulawesi where grazing pressure was well regulated (D.A. Kaligis, pers. comm.). Calliandra is utilised as a cut-and-carry feed in Bali and it appears to be better suited to cutting rather than to direct grazing.

Amarillo persisted very well and spread into adjacent paddocks. Buffalo grass was selectively grazed

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to 2 to 5 cm in height but continued to persist and spread slowly. *P. notatum* also persisted very well being less heavily grazed by stock. Its spread has been very slow as reported elsewhere (Kaligis and Sumolang, these proceedings).

Although the trial yielded relatively little animal production data it did provide important information

regarding the persistence of forage species to heavy grazing pressure. The ability of Floratam buffalo grass to persist and even spread under heavy grazing, and the apparent inability of *C. calothyrsus* to tolerate mechanical damage imposed through heavy grazing were of particular interest.

**Table 1.** Pasture treatments, planting method and contribution to dry matter (DM) by fraction 13 months after planting.

Pasture treatment	Planting method		Contribution to DM (%)					
	Initial	Replant	Planted grass	Planted legume	Native grass	Native legume	<i>Imperata</i>	Other weeds
Native pasture	–	–	–	–	16	15	60	9
<i>P. notatum</i> cv. Competidor	Seed	Cuttings	13	25	26	23	8	5
<i>A. pintoi</i> cv. Amarillo	Seed	Cuttings						
<i>S. secundatum</i> cv. Floratam	Cuttings	–	26	19	12	27	10	6
<i>A. pintoi</i> cv. Amarillo	Seed	Cuttings						
<i>P. notatum</i> cv. Competidor	Seed	Cuttings	2	55	14	16	7	6
<i>Caliandra calothyrsus</i>	Seedlings	–						



**Figure 1.** Grazing damage to *Calliandra calothyrsus* by cattle. Tree mortality occurred although less than 50% of bark was removed.

# Sheep Production by Transmigrant Farmers in a Plantation Area of North Sumatra

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## Transmigration Schemes in Indonesia

THE Government of the Republic of Indonesia has implemented transmigration programs during the past 40 years in an effort to reduce population pressure in Java and Bali. Transmigration programs can be divided into two groups: general and specific. In the general scheme, transmigrant farmers are granted 0.5 ha of land ready for planting food crops plus 2 ha of land requiring extra work to make it into a productive farming area. In the specific scheme, farmers are granted 0.5 ha of land ready for planting food crops plus an additional 2 ha of plantation land in the form of a loan. Both groups receive a living allowance for one year after transmigration.

## Sheep Integration into Oil Palm Plantations

The transmigration area at Sosa II, 96 km from Padang Sidempuan, the capital city of South Tapanuli, North Sumatra, is based on the specific scheme where each transmigrant received 2 ha of oil palm plantation and 0.5 ha land for food crops. In 1992, there were 500 families at this site earning an average income of about Rp. 3000000/family/month (around US\$136), mainly from oil palm production. However, while the oil palm is immature, incomes can be low. To address this problem, the Department of Transmigration requested that the Research Institution for Animal Production (Sub Balai Penelitian Ternak (SBPT) Sei Putih) investigate integrated animal production as a source of additional income for the farmers. The monthly income of these farmers before the introduction of animals was about US\$29.00 (Anonymous, 1993).

Sheep were chosen by SBPT Sei Putih as a suitable animal for the location because of their ease of man-

agement compared with other ruminants and their relatively rapid rate of reproduction. Manure, which can be easily used as an organic fertilizer for the food crop lands, was seen as an additional benefit. Substantial quantities of native forages were available in nearby oil palm plantations which could be supplemented with introduced forage species.

The aims of the involvement by SBPT Sei Putih were to diversify the farming system of the transmigrants and to increase farm income and man power utilisation through on-farm research. This paper reports the results of the scheme set up by SBPT at Sosa II, in which sheep production has become a profitable and sustainable activity in addition to cropping and plantation production.

## The SBPT Sheep Integration Scheme

The area is typified by flat topography, with an altitude of 110 m and rainfall of 2500 mm per year, of which 70% falls between October and April. The average temperature is 24°C. The soil is classified as a moderately acidic (pH 5) podzolic.

The scheme was started in March 1993 and involved 80 farmers. In the following financial year, an additional 40 farmers were included. Farmers were selected following an interview to assess their motivation for becoming involved in the scheme.

These original farmers were given credit consisting of:

- A barn measuring 2m × 3m,
- Five ewes, which became their own,
- One hair sheep crossbred ram, which was on loan.

The credit packet had to be repaid in the form of 10 ewes (each weighing more than 14 kg) and 1 ram (weighing more than 18 kg) within three years. These animals were then distributed to other farmers wishing to join the scheme. In this way, it was envisaged that the sheep population would expand rapidly. Rams were loaned rather than given to make it easier to rotate rams between farmers annually to avoid inbreeding.

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Each farmer was given free of charge, anthelmintic and mineral blocks, as these were considered to be essential for the success of the scheme. As the importance of these products become known to farmers, it is hoped that they will purchase them from their local animal health extension officers. Since the scheme commenced, there has been regular recording of live-weights, births, deaths and sales of animals.

All farmers participating in the scheme feed their animals using cut forages from the nearby plantations. However, farmers were also asked to plant 0.1 ha of *Paspalum dilatatum* and *Paraserianthes falcataria* (formerly *Albizia falcataria*) to supplement these cut forages. All planting materials were supplied by SBPT.

## Initial Sheep Production at Sosa II

Since the scheme began, the number of farmers has increased to 168; an increase of 40% above the original number of credit recipients (Table 1). The population of ewes in year 1 was reduced by 19 animals due to deaths following transportation to Sosa II from Sungei Putih. By July 1994, the number of adult ewes had increased by 31% and adult rams by 177%. The total number of lambs born since the beginning of the scheme was 1116. From the original number of credit animals given, the total sheep population in July 1994 had increased by 240%.

**Table 1.** Growth of farmer numbers and sheep population.

	Year 0 1992-93	Year 1 <sup>a</sup> 1993-94	Year 2 <sup>b</sup> 1994-95
Number of farmers	80	120	168
Number of animals			
Ewes:			
Adult	400	581	979
Lamb	0	329	588
Rams:			
Adult	80	120	333
Lamb	0	290	528
Total	480	1320	2428
Predicted number of sheep	480	1120	2280

<sup>a</sup> New additional packets (40 farmers); <sup>b</sup> until July 1994

The average birthweight of lambs is presented in Table 2. A slightly higher litter size of 1.5 for local Sumatran and 1.8 for a crossbred Sumatran × Garut was reported by Pitono et al. (1992). The distribution of birth types was 75%, 19% and 6% for singles,

twins and triplets respectively. The highest mortality occurred in triplets. This was expected since the competition between lambs during pregnancy and milking periods affected the survival rate (Donald and Russel 1970; Fitzhugh and Bradford 1983). Average preweaning mortality was less than 5%, which is markedly lower than for experimental flock at Sungei Putih where preweaning mortality averages 22%. The average daily gain of lambs postweaning was 50–60 g/head/day, without any form of supplementation. The very low mortality rate and reasonable postweaning growth rates can be partly attributed to good care of young lambs and partly to very low worm burdens as a result of regular drenching and the feeding of cut-and-carry forage only. Measurements made in February 1994, showed that three-quarters of all animals had a low level of worm infection.

Using the assumptions of a lambing interval of 8 months, litter size of 1.3 lambs and a total mortality of 10%, the numbers of sheep can be predicted. New ewes were mated at 9 months old. Predicted numbers of sheep were lower than actual numbers (Table 1), because of the low rate of mortality during the pre- and postweaning periods (Table 2).

Using the above assumptions, the total sheep numbers per farmer in March 1995 could be predicted to be 28 head, consisting of 6 original animals and 22 head of their generation. From these 22 sheep, 11 sheep would be taken for payment of credit. Each farmer would then have a flock of 17 sheep consisting of: one ram; five 2-month pregnant ewes; three 4-month pregnant ewes; two 4-month lamb ewes; three 2-month lamb ewes; and three 2-month lamb rams.

It was predicted that by March 1996, the farmer would be able to sell 24 sheep equivalent to a net monthly income of US\$40, (Table 3) while maintaining the same flock size of 17. The composition of the flock would remain as shown in March 1995 figures. Annual sales and income would increase slightly by March 1997 (Table 3).

Since the scheme began, there has been a demand from farmers wishing to join the scheme.

## Future Plans For The Scheme

The rapid expansion of sheep numbers since this first scheme commenced, along with the generally high-level of enthusiasm shown by farmers for the concept of sheep credit packets, has resulted in plans for similar schemes to be developed in adjacent transmigration areas. (Sosa III a and b, IV, V and VI).

These new schemes will involve an on-farm research component investigating the use of forage tree legumes, and locally available byproducts of agriculture and industry as feed supplements.

Lack of medical and mineral supplies available at the location will be one of the future problems as will

**Table 2.** Lamb population, average birthweight, average liveweight gain, and mortality between March 1993 and March 1994.

	Total lambs	Average bodyweight (kg)	Average liveweight gain (g/hd/day)	Mortality	
				No.	%
Newborn:					
Female	329	1.7	–	5	1.5
Male	290	1.8	–	4	1.4
Birth type:					
Single	369	2.0	–	0	0
Twins	182	1.7	–	1	0.6
Triplets	78	1.3	–	8	10.3
Weaners:					
Female	324	8.2	51	6	1.9
Male	286	8.8	60	5	1.8

**Table 3.** Predicted returns in number of sheep and US\$ for each farmer starting at the end of the third year (March 1995).

	March 1995	March 1996	March 1997	March 1998
Total (head)	17	41	45	45
Sold		24	28	28
Price/head		23	23	23
Gross income		546	636	636
Expenditures <sup>a</sup>		65	68	68
Net income/year		480	568	568
Net income/month		40	47	47

<sup>a</sup> Expenditures including mineral blocks, fertilizers, medical supplies and repairs of barn.

the problem of rotation of rams. It has been suggested that the farmers form a cooperative specifically for sheep farmers (Koperasi Ternak). All supplies required will then be organised by this Koperasi Ternak while the local extension office would provide advice on animal health problems.

The success of the scheme at Sosa II has led the Department of Transmigration to propose a new form of

transmigration in which farmers would be given 2.0 hectares of land for production of forages and crops together with 25 ewes and 2 rams. The scheme is locally called 'TIRNAK' (animal production as the main source of income), and is still in the conceptual stage. However 150 packages are being planned to evaluate the potential income from this form of transmigrant scheme.

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# Sheep Under Rubber: Prospects and Research Priorities in Indonesia

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THE potential benefits and constraints of sheep production in rubber plantations have been discussed elsewhere (Iniguez and Sanchez, 1991; Shelton and Stür 1991; Sivraj et al. 1993). Sheep are the most suitable animals for grazing in rubber plantations, being easier than goats to manage in small or large flocks and having little or no effect on plantation production (Horne et al. 1994a). Local sheep breeds in Indonesia are reasonably productive, relatively disease-resistant and well adapted to the agroclimate of the region. For these reasons, collaborative research between the Indonesian Animal Husbandry Research Institute at Sungai Putih (SBPT-SP) and the Small Ruminant Collaborative Research Support Program (SR-CRSP) was started in 1984 to develop technologies for integrated sheep-rubber production systems. A sheep flock was located at Sungai Putih in North Sumatra (3°N, annual rainfall 1830 mm) as the focus for research on breeding, feed resources and nutrition, socioeconomics and animal health. This paper summarises the main findings of the research and highlights key future research priorities. Unless otherwise stated, all research cited in the paper relates to experiments conducted by SR-CRSP at Sungai Putih.

## Feed Resources and Nutrition Research

Sheep-rubber integration systems aim to utilise existing or potential forage resources in rubber plantations. Forages form the basic feed for both extensive (commercial) and intensive (smallholder and commercial) production systems. Native forages in plantations however, have limited potential for animal production (Chong et al. unpublished data) SR-CRSP research on feed resources and nutrition has

been based on improving the forage resource in rubber plantations, and on the use of agroindustrial by-product supplements to alleviate dietary protein, energy and mineral deficiencies.

### Native forages

The common native forages of mature rubber plantations in North Sumatra, including the grasses *Cyrtococcum oxyphyllum*, *Ottlochloa nodosa*, *Paspalum conjugatum*, *Setaria palmiflora* and *Axonopus compressus*, and the forb *Mikania cordata*, have adequate crude protein levels (>12%) and low-to-moderate in vitro dry matter digestibilities. As a result, moderate growth rates of unsupplemented weaned lambs at low stocking rates of 40–90g/head/day have been achieved in North Sumatra from these forages, both from flocks on large plantations and from flocks in villages (Sanchez 1991; Verwilghen et al. 1992). However, the very low productivity of native forages in mature plantations, results in low sustainable stocking rates of 2–4 ewes/ha (Chong et al. unpublished data). To satisfy intake requirements sheep need either longer grazing times or additional barn feed. Eight hour's grazing time per day is generally required to satisfy the dry matter intake requirements of sheep grazing in mature rubber plantations.

### Improved forages for young rubber

In young plantations, there is significant potential to increase stocking rates by replacing traditional cover crops (which yield only 5–7 t DM/ha/year) with improved forages (with the potential to produce 12–15 t DM/ha/year). From a small sward, evaluation of monocultures and mixtures of 22 grasses and legumes was conducted from 1988 until 1992. The most productive and persistent accessions in the shaded conditions of semi-closed rubber canopies were *Brachiaria humidicola* cv. Tully, *Panicum maximum* cv. Hamil and *Stylosanthes guianensis* cv. Cook. These accessions, along with the more recent introductions, *Paspalum notatum* cv. Competidor and the legumes *Arachis pintoi* cv. Amarillo and *Stylosanthes guianensis* CIAT 184 have

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been sown in mixtures to investigate their productivity, persistence and capacity to support animal production (both liveweight gain of lambs and reproductive performance of ewes) under grazed and cut-and-carry systems in a young rubber plantation.

### Forage improvement opportunities for rubber producers in Indonesia

In Indonesia, the potential for improving the forage resource of conventional rubber plantations with introduced grasses and legumes is limited to young plantations on large estates. However, 83% of the rubber plantation area is controlled by smallholders, of which only 21% are supervised by large Nucleus estates (NES farmers), with the remainder being jungle rubber producers. Opportunities for forage improvement within the plantations of the NES farmers are limited. These farmers normally plant cover crops or food crops in the interrows of the immature rubber. Even with financial assistance from the Nucleus estate to establish improved forages under their young rubber, they face the problem of having to rapidly reduce their sheep numbers as the forage yields decline with canopy closure. The best opportunity for forage improvement for NES smallholders lies in the planting of acid-tolerant grasses and tree legumes in cropping and homeyard areas. In some areas, the supervised smallholders have abandoned their cropping areas after several years, as the soils are too acid and infertile to sustain productivity. Many forage species are better adapted to these conditions than the usual dryland crops and a range of these, (including many from CIAT), is being evaluated at Sungei Putih. Even so, lime will normally be required to neutralise low pH and supply calcium, with other additions of phosphorus, magnesium, sulfur and potassium possibly being required (Horne et al. 1993)

Tree legumes are particularly well adapted to the needs of NES smallholders. The common local tree legume genera (*Calliandra*, *Paraserianthes*, *Leucaena*, and *Gliricidia*) are generally persistent, easy to grow, can be planted in small areas of wasteland and can be harvested to provide a highly-digestible protein supplement at strategic times. SR-CRSP has conducted feeding trials with the more common tree legume species and is commencing on-farm trials with smallholders. *Gliricidia sepium* is a particularly promising species with 5-7 lines from the Oxford collection exhibiting good pest tolerance and regrowth and yield potential (7-9 t edible DM/ha/year).

### Byproduct supplementation

With a few exceptions, providing grazing ewes at Sungei Putih with dietary energy supplements has

been more beneficial to reproductive performance than supplementing with sources of fermentable nitrogen. However, the potential benefits of bypass protein need further research (Reese 1988; Sanchez and Boer 1989; Boer and Sanchez 1989; Sanchez and Pond 1989). Batubara et al. (1994) also found that supplementation of weaned lambs with dietary energy was economically beneficial. Higher weight gains of lambs were achieved at higher levels of energy intake (121 g/head/day at 0.24 Mcal DE/kg  $BW^{-0.75}$ ) compared with lower levels of energy intake (86 g/head/day at 0.19 Mcal DE/kg  $BW^{-0.75}$ ).

Although continuous supplementation of ewes with a concentrate mix containing energy supplements gave significant increases in ewe productivity (1.13 kg lamb weaned per ewe per year for supplement at 1.4% BW compared with 0.92 for the unsupplemented control), continuous supplementation of ewes with concentrate mixes has proved uneconomic (Reese 1988; Sanchez 1991). Supplementation research at Sungei Putih is now focusing on the continuous supplementation of weaned lambs and only strategic supplementation of ewes (during late pregnancy and lactation).

The most promising locally available byproducts that can be used as sources of energy supplementation are: molasses, palm kernel cake, cassava meal and rice bran. In supplementation experiments using various combinations of these byproducts, lamb growth rates increased by between 27 and 65% over unsupplemented control animals. In most cases supplementation proved economically viable (Sanchez 1991). Molasses can be simply fed in self-feeder troughs or as part of molasses-blocks. A typical block will contain 40-48% molasses, 25-35% rice bran, 15% cement, 5% salt and 10% commercial mineral mix, with intakes by sheep expected to be 20-50 g/head/day (Pond et al. 1994).

Results from two experiments on strategic supplementation with byproducts, and one experiment on continuous supplementation with molasses are presented in Table 1. Supplementation resulted in significant increases in milk production, and hence lower mortality and higher weaning weights of lambs. Continuous supplementation with molasses proved simple and effective. Most of these supplementation strategies were considered economic, although the cost and logistics for smallholders make supplements such as molasses impractical.

### Mineral supplementation

The use of mineral supplements is essential to overcome widespread dietary deficiencies of macro- and microminerals. Although the type and degree of deficiencies vary greatly across regions, deficiencies of Na, P, Zn, Cu and I are common in Southeast Asia. Farmers often provide salt by adding it to

drinking water, sprinkling it on forage and providing bamboo salt licks. At Sungai Putih, mineral analyses of native and introduced forages have indicated the particular need for supplementation with Na and P (Pond et al. 1994).

Commercial mineral mixes incorporated in molasses blocks (as described above) or mineral blocks are a simple and relatively cheap way of overcoming these deficiencies. A typical mineral block at Sungai Putih contains 69% salt, 20% commercial mineral mix (Ca 20%, P 25%, Na 22%, Mn 0.35%, Zn 0.20%, Fe 0.80%, I 0.2% and Cu 0.15%) and 11% cement. The blocks can be made in small buckets and dried in the sun. A small wire hook set into each block allows the block to be hung from the ceiling of the barn. Formulas for the blocks may need to be adjusted to overcome particular local and/or severe deficiencies. Work is continuing at Sungai Putih on the production of mineral blocks by smallholder farmers for their own sheep.

### Waste products

Some of the promising byproduct feed supplements, such as palm kernel cake and cassava meal, are relatively expensive. A range of waste products from plantation agriculture have potential as alternative

supplements. These include waste products from palm oil extraction, collectively known as palm oil mill effluent (POME), and waste products from cocoa production (cocoa seed waste, fruit and leaf from the *Flemingia macrophylla* used as a shade crop). All of these wastes are being investigated at Sungai Putih. Of the POME wastes, ex-decanter solid waste (EDSW) has the greatest potential as animal feed (Yeong and Azizah 1987). A typical decanter-system factory that processes 800 tons of fresh oil palm fruit per day, yields 12 tons of EDSW per day and there are nine such factories in North Sumatra alone. EDSW has a crude protein content of about 15%, an estimated energy content of 2.4 Mcal DE/kg and digestibilities of dry matter, protein and energy in the range of 55–65%. Feeding trials conducted at Sungai Putih in North Sumatra indicated that incorporation of EDSW at up to 21% in the diets of growing lambs can reduce the costs of concentrate supplements by 40% with no reduction in growth rates (Horne et al. 1994b).

### Breeding research

The Sumatran (S) sheep breed is indigenous to North Sumatra. It has a high reproductive potential in comparison with temperate sheep, but is small and often woolly (adult ewes averaging 22kg). The sheep

**Table 1.** Productivity of ewes receiving supplements, either strategically or continuously (figures in brackets indicate the percentage change relative to the unsupplemented control)<sup>a</sup> (Sources: Sanchez 1991; Sanchez and Pond 1991, Ginting et al. 1992).

	Sheep breed	
	Virgin Island White (H) <sup>d</sup>	Sumatran
Concentrate supplement <sup>b</sup>		
Lamb weight/lambing (kg)	14.5 (145%)	9.7 (102%)
Lambing interval (days) <sup>c</sup>	228 (96%)	213 (85%)
Kg lamb/ewe/year	24.1 (143%)	16.9 (118%)
Kg lamb/kg ewe/year <sup>c</sup>	0.84 (129%)	0.76 (112%)
Gliricidia + rubber seed meal <sup>d</sup>		
Kg lamb/kg ewe/year	–	0.93
Molasses <i>ad libitum</i> <sup>e</sup>		
Lamb weight/lambing (kg)	–	11.4 (124%)
Lambing interval (days)	–	216 (93%)
Kg lamb/kg ewe/year	–	0.88 (124%)

<sup>a</sup> Differences between breeds and between supplemented and control treatments are significant ( $P < 0.05$ ) except where stated otherwise.

<sup>b</sup> Strategic supplementation (last six weeks of pregnancy and lactation) with rice bran 44.2%, cassava meal 31.3%, molasses 20.7%, fish meal 1.4%, urea 1.0% and limestone 1.4% given at 1.4% of BW.

<sup>c</sup> Breed effect non-significant ( $p > 0.05$ ).

<sup>d</sup> Strategic supplementation (last two weeks of pregnancy and six weeks of lactation) with rubber seed meal and gliricidia given at 0.6% and 0.45% of BW respectively.

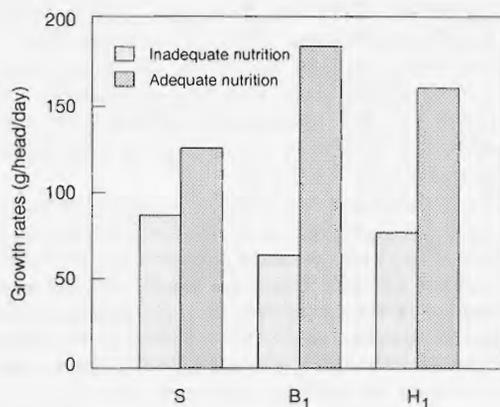
<sup>e</sup> Continuous supplementation.

breeding program at Sungei Putih is evaluating the Sumatran crossbred with three larger breeds of tropical hair sheep; the Virgin Island White (H), the East Javanese Fat-tail (E) and the Barbados Blackbelly (B) with the aim of producing crossbreeds of wool-free sheep with superior performance to the Sumatran (Gatenby et al. 1993a). A 50% composite strain of S and H (designated HC), a 50% strain of S and B and a composite strain of 50% S, 25%B and 25%H are also being produced by selection of superior ewes based on a productivity index [(total weight of lamb weaned) / (age of ewe at second lambing - 200days)] at the time of second lambing.

Comparative productivity traits from the first simultaneous lambing of the three F<sub>1</sub> crosses and S are presented in Table 2. Weights of SB (B<sub>1</sub>) and SH (H<sub>1</sub>) lambs from birth until nine months of age were significantly higher than from S. B<sub>1</sub> tends to have the least wool and S to have the most wool. Across all breeds, litter size averaged 1.55 with a distribution of 54%, 38%, 7% and 1% between litter sizes of 1, 2, 3 and 4 respectively. Lamb mortality rates were similar for all four breed groups, with preweaning mortality averaging 22%. The selected strain of H<sub>1</sub>-HC ewes produced 13% greater weight of lamb weaned per kg of ewe per year than the selected strain of S ewes and 20% greater weight of lamb weaned per kg of ewe metabolic weight per year. The latter result shows that the productivity difference between the two groups is a true breed effect and not just due to differences in ewe body weight.

These and subsequent results indicate that the crossbred animals (especially crosses with H and B) are larger and have a superior reproductive potential

than the Sumatran. However, Horne et al. (1994b) show that, while at adequate levels of supplementation, growth rates of lambs of B<sub>1</sub> and H<sub>1</sub> breed types (185 and 161 g/head/day) were significantly higher than those of Sumatran lambs (125 g/head/day), there were no significant differences in growth rates between all three breeds at inadequate levels of dietary supplementation (76 g/head/day) (Fig. 1). This result indicates that for the hair sheep crossbreeds to achieve their potentially higher growth rates, improved feed resources are essential.



**Figure 1.** Growth rates of weaned ram lambs of Sumatran (S), Barbados Blackbelly × Sumatran (B<sub>1</sub>) and St. Croix × Sumatran (H<sub>1</sub>) breed types at two levels of nutrition.

**Table 2.** Mean production parameters for four sheep breed types (Sources: Gatenby et al. 1993a; Gatenby et al. 1993b).

	S <sup>a</sup>	E <sub>1</sub> <sup>b</sup>	H <sub>1</sub> <sup>c</sup>	B <sub>1</sub> <sup>d</sup>
Crossbreeding program, unselected animals				
Birthweight of all lambs (kg)	1.71 a	1.82 ab	1.95 b	1.97 b
Three-month weight of all lambs (kg)	7.8 a	8.8 b	9.0 b	10.3 c
Nine-month weight of female lambs	16.6 a	17.2 a	19.0 b	19.9 b
Wool score at nine months <sup>e</sup>	52.3	38.6	34.3	17.9
Selection program <sup>f</sup>				
Adult ewe weight	23.1	—	30.2	—
kg lamb weaned per ewe	15.2 a	—	22.4 b	—
kg lamb weaned/kg ewe/year	0.67 a	—	0.75 b	—
kg lamb weaned/kg <sup>0.75</sup> ewe/year	1.45 a	—	1.75 b	—

Numbers within rows with different letters are significantly different (p<0.05)

<sup>a</sup> S = Sumatran

<sup>b</sup> E<sub>1</sub> = East Javanese Fat-tail × S

<sup>c</sup> H<sub>1</sub> = Virgin Island × S

<sup>d</sup> B<sub>1</sub> = Barbados Blackbelly × S

<sup>e</sup> Wool score = wool cover score (0–9) × wool length score (0–9)

<sup>f</sup> Both H<sub>1</sub> and HC ewes were included in the H<sub>1</sub> category.

## Animal health research

The beneficial effects of supplementation described above were obtained from experiments in which the use of anthelmintics was routine. Without control of gastrointestinal parasites it is unlikely that supplementation would be economic. Gastrointestinal worms, especially *Haemonchus*, are the single most serious and constant health problem for sheep in North Sumatra and contribute to major production losses and lamb mortality. Pasture rotation once every three months, concurrent anthelmintic treatment and yearly rotation of the chemical group of anthelmintic are the simple measures used to control gastrointestinal worms and limit the development of anthelmintic-resistant worms in the experimental flock at Sungai Putih. However, reinfestation with worms following anthelmintic treatment is normally rapid, with faecal egg counts reaching pretreatment levels after only 4–6 weeks.

Comparisons of faecal egg counts (epg) and packed cell volumes (PCV) between the sheep breed types at Sungai Putih have revealed no significant differences between the hair sheep crossbreeds and the local Sumatra sheep in susceptibility to gastrointestinal worms (Batubara et al. 1993). However, differences between individual sheep within breeds can be large, with some maintaining consistently low or consistently high faecal egg counts. This large variability in resistance between individuals offers an opportunity for selection of lines of flocks with resistance to gastrointestinal worms. This has shown to be feasible in sheep flocks in Australia, with heritabilities of resistance traits up to 0.3–0.5 (Pandey et al. 1994). Selection for resistance may be especially useful in those tropical areas where pasture rotation and strategic use of anthelmintics are not effective control measures because of the spread of anthelmintic-resistant parasites (Pandey and Sivaraj 1994). At Sungai Putih a research program has commenced to select and compare the longer-term performance of 'susceptible' and 'resistant' lines of hair sheep crossbreeds using artificial infections of *Haemonchus contortus*.

## Socioeconomics research

Credit schemes at several locations in North Sumatra organised by the SR–CRSP and SBPT, have provided over 120 farmers with flocks of sheep of between 4 and 16 ewes. These farmers are required to repay the credit in the form of twice the number of ewe lambs originally given within 3–4 years. These ewe lambs are then provided to other farmers. Technology transfer has focused on mineral blocks, anthelmintics, ram rotation and supplementation with tree legume leaf, with varying degrees of success. All schemes have started to expand rapidly after an initial lag phase. Gross margin analyses of

NES farmers who have received such credit shows that net farm income can be increased by \$US196/year/farm by rearing sheep, which is approximately 22% of the estimated net income from rubber (Kartamulia et al. 1993). Similar analyses of sheep farmers who surround, but do not own, rubber plantations have shown that with an average flock size of 20 ewes a farmer's annual income can increase by around 25% (\$US600) from sheep rearing. Economic analyses of fattening enterprises for larger plantations show that such schemes need to be relatively large to be economically viable. A break-even flock size was estimated to be 60 animals with a net return on investment from 200 animals of about 18%. (Batubara et al. 1992).

With an estimated growth rate of 4% per annum, domestic demand for sheep meat continues to exceed supply. With the current market price for sheep of around \$US1.00–1.50/kg liveweight, the outlook for the domestic market appears to be strong. In addition, with the development of the Indonesia–Malaysia–Thailand Northern Growth Triangle trading agreement, substantial export markets for sheep from northern Sumatra have been developed.

A study of the economics of anthelmintic treatment of sheep in villages indicated that an increase in productivity over a ewe's lifetime of approximately 29% (equivalent to \$US22.50) is possible for an investment of only \$US2.00 (Scholz 1992). However, smallholders either have difficulty finding a supplier of anthelmintics or the suppliers only provide prepacked large quantities which the farmers cannot afford. Alternative methods of delivery of animal health products to villages are being investigated.

## Priorities for future research

From the work that has been completed so far, some key future research priorities are as follows:

- With the development of the Indonesia–Malaysia–Thailand Northern Growth Triangle and the resulting move towards developing commercial sheep production enterprises in northern Sumatra, economic analysis of large-scale sheep enterprises incorporating SR–CRSP and SBPT technologies and more detailed analysis of potential export markets are required.
- Expansion and privatisation of an animal health delivery network set up by the SR–CRSP is proposed to incorporate more farmers and include the distribution and sale of both anthelmintics and privately produced mineral blocks.
- It is likely that the composite breed that will be recommended for rubber plantations in North Sumatra will be the 50% S, 25% B and 25% H. This breed type will need to be stabilised and developed for distribution through a breeding and selection program.

This is a major undertaking and will need substantial planning and institutional support.

- Controlling gastrointestinal worms (primarily *Haemonchus contortus*) through pasture rotation and the use of anthelmintics is feasible for commercial enterprises on large plantations, but is a strategy that is vulnerable if anthelmintic resistance develops. Most smallholder farmers can neither control the use of their communal grazing lands nor have access to anthelmintics. More detailed research is needed on the level and types of gastrointestinal worm infections of sheep in North Sumatra.
- Pasture rotations of three months duration have been shown to be a reasonably effective measure for controlling the level of infective worm larvae on the pasture. However, if improved forages (especially grasses) are to be used with rotational grazing, rotations of only 4–6 weeks are required to optimise forage quality and yield. Research is needed to identify pastures that can be rotated over 2–3 months and still maintain reasonable quality.
- Research on the potential for developing worm-resistant sheep breeds has commenced at Sungei Putih and will be continued. This is a long-term undertaking, however.
- The main limitation to research on improved forages for conventional rubber plantations is the long period of negligible yield following canopy closure. The most promising solution is to alter the planting pattern of the rubber trees, as described by Chong and Tajuddin (these proceedings), to allow sustainable production of higher-yielding forages as an integral part of the plantation. Experiments are now well advanced in Malaysia using the double hedgerow system. Large experiments are being conducted in Indonesia based on the concept of changing planting patterns to diversify rubber plantation agriculture (primarily with timber crops). Work is needed in Indonesia to investigate alternative planting patterns and incorporating aspects of forage management, supplementation, sheep breeding and animal health management as a whole farm concept.
- Experiments on supplementation of ewes and lambs have identified several useful agroindustrial byproducts (especially molasses, palm kernel cake, rice bran and cassava meal). In some areas, plantation waste products and shade crop leaves have potential as animal supplements and deserve further investigation. The results of these experiments need to be developed into economic forage and feed supplementation strategies for smallholders and commercial producers.

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# Sheep Production under Conventional Rubber Systems in Malaysia

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THE planting of grasses into rubber plantations is not encouraged because the grass species competes strongly with rubber for water and nutrients. However, the planting of legume cover crops has been accepted as good agronomic plantation practice because of their ability to provide quick ground coverage, fix atmospheric nitrogen and increase soil organic matter content. The integration of livestock into plantations has been limited by the poor productivity and persistence of naturalised forages (Wong and Stür 1993) and cover crops, and therefore improved forage species have been sought (Chong et al. 1991). Ideally these forages should provide persistent, high quality feed without affecting rubber growth and production.

In this study, a 'best-bet' grass-legume mixture identified from earlier small plot experiments (Ng 1991), was compared with both grazed and ungrazed cover crops. Sheep and pasture production and rubber growth and yield were assessed. This paper reports the preliminary results of this experiment.

## Materials and Methods

### Site

The experiment was located at RRIM Experimental Station (RRIES), Sungai Buloh in a rubber replant area. Mean annual rainfall at RRIES Sg. Buloh (1977–1989) is 2190 mm and well distributed throughout the year, with a minimum of 110 mm/month during the drier months of June and July. The soil type is coarse sand with a pH 4.8 and is deficient in N, P, K, Ca and Mg.

### Experimental design and treatments

The experiment was a randomised complete block design with 3 replications. Grazed treatment plots

were 0.5 ha in area and the ungrazed cover crop plots were 0.1 ha. Treatments included:

- Ungrazed *Pueraria phaseoloides* cover crop (T1),
- Grazed *P. phaseoloides* cover crop (T2), and
- Grazed grass-legume mixture (T3) consisting of high light species *Brachiaria humidicola* cv. Tully, *Stylosanthes guianensis* cv. Endeavour and *S. hamata* cv. Verano and low light species *Paspalum wettsteinii*, *P. notatum* cv. Competidor, *Stenotaphrum secundatum* cv. Floratam and *Arachis pintoi* cv. Amarillo.

It was hypothesised that the low light species in treatment 3 would become dominant as light transmission through the rubber canopy dropped below 50%.

### Rubber and pasture establishment

Rubber planted at conventional spacing of 6 × 4 m (416 trees/ha), was followed by plantings of cover crop and grass-legume treatments in September 1991. A basal fertilizer, consisting of ground magnesium limestone at 2 ton/ha and Christmas Island rock phosphate (CIRP) at 0.5 t/ha, was broadcast and ploughed into the soil before planting. Grazed treatments were top dressed with 20 kg N, 100 kg K<sub>2</sub>O, 1 kg Cu and 1 kg Zn per hectare applied 2 months after planting, and again 6 months later (except N).

### Grazing

A simple grazing management system was followed. Twelve core animals, consisting of post-weaned (50% Dorset/Marlin) male lambs 4–5 months old, were assigned to each of the two grazed treatments. Extra sheep (older male lambs) were also included in the grazing treatment as put/take animals to maintain similar pasture availability by keeping pasture at approximately 600–1200 kg DM/ha. Sheep were allowed to graze in each of the replicates for 2 weeks; replicate 1 in weeks 1 and 2, replicate 2 in weeks 3 and 4, and replicate 3 in weeks 5 and 6 before coming back to replicate 1 for the next cycle. Two groups of followers of 10–12 sheep were assigned to each treatment to make up the required stocking rate

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to evenly graze down the pasture to similar residual levels following the set grazing period. Stocking rates (SR) were equivalent to 8 lambs/ha for the cover crop and 16 lambs/ha for grass-legume pasture.

### Measurements

Measurements on forage yield and species composition were estimated by cutting samples using 0.5m<sup>2</sup> quadrats. For a realistic estimation of the forage in the interrows, samples from 5 quadrats which formed a cutting strip (band) across the interrows were harvested. Six bands were harvested in T1 whereas 12 bands were harvested in T2 and T3.

The number of grazing days in each replicate (core animals plus put/take animals) were used for calculations of SR at the end of each 6-month grazing period. Sheep were weighed monthly.

Rubber girth measurements were taken at 2 and 2.5 years after planting.

## Results and Discussion

Sheep grazing commenced in May 1994, 32 months after pasture planting. Grazing was delayed because the rubber trees were small and unsafe for earlier grazing. As a general guideline, sheep can be introduced into two-year-old rubber provided trees are vigorous in growth and have developed 2 m of brown bark.

### Pasture botanical composition

The pasture treatments were at an optimal stage for first grazing at eight months after planting when all treatments were well established and weed species were being effectively controlled (Table 1). The grass-legume treatment was *Sylosanthes* dominant initially but grass species had established well and were spreading. The 32-month delay to first grazing allowed the grass species, predominantly *B. humidicola*, to dominate and legume yield dropped sharply. *Paspalum*

*notatum* cv. Competidor was the only low-light requiring species to establish strongly and its contribution to DM increased over the ungrazed period.

Over the same period, the cover crop treatments became progressively invaded by weeds, in particular *Asystasia intrusa*. The grass-legume treatment was more resistant to weed invasion. Additional phosphorus supplementation of the cover crop treatments may have improved their ability to compete with weeds (Tajuddin Ismail, personal experience). The pregrazing presentation yields of cover crop treatments were higher than for the grass-legume treatment (Table 1) due to the slashing of the latter treatment to improve its palatability to sheep.

### Rubber growth

Girth of rubber trees was highest for the ungrazed cover crop treatment and lowest for the grazed grass-legume treatment (Table 2). This result supports earlier findings that grass pastures depress growth of rubber (Watson et al. 1964). In this experiment, the long delay to first grazing would have exacerbated the competitive effect of the grass species. Two management options are available to overcome the lag period to grazing, including the use of core-stump rubber seedlings and the delaying of planting of pasture species. With the onset of grazing the improved nutrient cycling in the grazed treatments may reduce the differences in growth rates.

### Animal production

Stocking rate (SR) was adjusted according to forage availability. From preliminary grazing data (118 days), the grass-legume treatment supported twice the stock number of the legume cover crop treatment but individual daily liveweight gains (ADG) were very low (Table 3). Excellent individual liveweight gains (LWG) from the *P. phaseoloides* legume cover crop and the naturalised forages reflects the high

Table 1. Presentation dry matter and botanical composition in conventionally planted rubber.

Treatments	DM yield (kg/ha)	Botanical composition (%)				
		Cover crop	Grass for high light	Legume for high light	Low light mixture	Weeds
Cover crop ungrazed	680	93	-	-	-	7
	1200	43	-	-	-	57
Cover crop grazed	750	95	-	-	-	5
	1160	48	-	-	-	52
Grass-legume grazed	1000	-	29	63	6	2
	870	-	70	14	14	2

1st row, October 1992 (8 months after pasture establishment)

2nd row, April 1994 (Pre-grazing, 32 months after pasture establishment).

quality and palatability of these species. Patch grazing of the *B. humidicola* dominant grass-legume pasture was in part overcome by the high stocking rate rotational grazing system adopted, however sheep in this treatment soon developed heavy gastrointestinal worm burdens. Management practices need to be developed to overcome patch grazing and palatability problems, as well the heavy worm burdens, if *B. humidicola* is to be used as a forage for sheep.

**Table 2.** Rubber girth increment for treatments.

Treatment	Girth at 2 years (cm)	Girth at 2.5 years (cm)	Increment (cm)
Cover crop ungrazed	12.9	16.4	3.5
Cover crop grazed	12.1	15.3	3.2
Grass-legume grazed	10.5	13.6	3.1

**Table 3.** SR, ADG and LWG of sheep grazing on improved and legume cover crops in conventionally planted rubber.

Treatment	SR (lamb/ha)	ADG <sup>a</sup> (g/lamb/day)	LWG (kg/ha/yr)
Cover crop	8	114	333
Grass-legume	16	36	210

<sup>a</sup> Period: 4 May 1994–30 August 1994.

## Conclusions

*B. humidicola* based grass-legume pastures effectively controlled weeds but adversely affected rubber growth during the rubber establishment phase. Legume cover crops were conducive to good rubber growth but their ability to suppress weeds was short-lived unless phosphorus nutrition was maintained. Animal production from *B. humidicola* dominant pastures was severely limited due to grazing management and animal health problems. Far superior individual liveweight gains were achieved from the legume cover crop pasture but only low stocking rates were sustainable.

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# Grazing Sheep on Improved Pasture under Double Hedgerow Rubber Planting Systems in Malaysia

Chong Dai Thai\*, Tajuddin Ismail\*, and W.W. Stür†

MALAYSIA is one of the world's major producers of oil palm, rubber and cocoa and the plantation sector is important to the country's socioeconomic development. The vast areas under plantation crops have great potential for livestock integration. However, the progress of livestock integration into plantations has been slow due to problems of low forage and animal productivity.

Chong et al. 1995, reported that while sheep grazing naturalised forages achieved a maximum live-weight gain (LWG) of 467 kg/ha/yr under 2–3-year-old rubber, LWG declined rapidly to 30–72 kg/ha/yr in mature 7-year-old rubber. As conventionally planted rubber cannot be grazed until it is 2-years-old, the period of acceptable sheep production under rubber is very limited. Alternative plantation management systems need to be developed for long-term sheep integration under rubber.

The Rubber Research Institute of Malaysia (RRIM) has been investigating a double hedgerow rubber planting system comprising two rows of rubber trees with a wide alley between the adjacent hedges. The main attraction of this system is that it provides continuous high-light conditions in the alley for the development of other forms of permanent agricultural production.

This paper reports on the preliminary results of a grazing experiment comparing two types of improved pasture for sheep production, established in a double hedgerow rubber planting system (Fig. 1). Pasture species selected consisted of both high-light (>50% light transmission) and shade-tolerant species. The species for low-light were selected for their ability to maintain a dense ground cover under the reduced light transmission conditions experienced close to the rubber hedgerow.

The main objectives of the experiment were to measure rubber, forage and sheep productivity from

improved pasture under a double hedgerow rubber planting system and to assess the sustainability of the pasture system.

## Materials and Methods

### Site

The experiment was located at RRIM Experimental Station (RRIES), Sungai Buloh in a rubber replant area. Mean annual rainfall at RRIES Sg. Buloh (1977–1989) is 2190mm. Rainfall is well distributed throughout the year with a minimum of 110 mm/month during the drier months of June and July. Soil type is a coarse sand with pH 4.8 and deficient in N, P, K, Ca and Mg.

### Experimental design and treatments

The experiment used a randomised complete block design with 3 replicates. Each paddock was 0.25 ha in area and these were subdivided into 4 sub-paddocks for grazing management.

- Treatments consisted of two pasture types including:
- Nitrogen-fertilised grass—*Brachiaria humidicola* cv. Tully and *Paspalum notatum* cv. Competidor fertilised with 200 kg N/ha/yr.
  - Grass-legume mixture—*Brachiaria humidicola* cv. Tully, *Paspalum wettsteinii*, *Paspalum notatum* cv. Competidor, *Stylosanthes guianensis* cv. Endeavour, *Stylosanthes hamata* cv. Verano, *Arachis pintoi* cv. Amarillo and *Stenotaphrum secundatum* cv. Floratum.

### Rubber and pasture establishment

Basal fertilizer, comprising ground magnesium limestone at 2 t/ha and Christmas Island rock phosphate (CIRP) at 0.5 t/ha, was incorporated into the soil before planting. Annual maintenance fertilizer of 60 kg P<sub>2</sub>O<sub>5</sub> and 100 kg K<sub>2</sub>O per hectare, was applied to both treatments with an additional 200 kg N/ha/yr applied to the nitrogen-fertilised pasture.

Rubber was planted in September 1991 and pasture treatments were planted 7 months later in April

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1992 during the wet season. The rubber (clone RRIM 901) was planted as 3-whorl polybag plants in a double hedgerow configuration (Fig. 1). Rubber trees were fertilised using standard RRIM management practices and weeds in the rubber rows were sprayed with herbicides before fertilizer applications. Eighteen and 4 rounds of weeding were carried out during the second and third years of the experiment respectively.

With the exception of *S. secundatum*, all pasture species were planted from seed in 0.8 m wide rows. Cuttings of *S. secundatum* were planted in rows spaced 1 m apart.

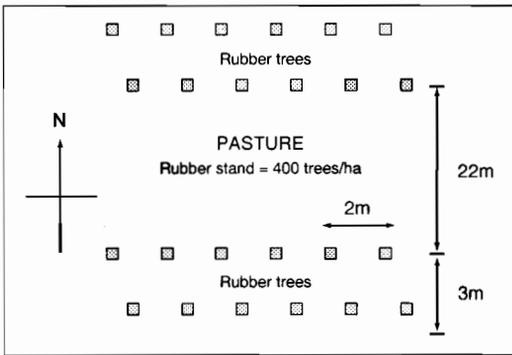


Figure 1. Hedgerow rubber planting system.

### Grazing management

Crossbred Dorset/Marlin sheep began grazing 8 months after the planting of pasture. Four core animals plus other animals (extras) grazed in each paddock for 1 week and returned to the same paddock after 3 weeks. Sheep stocking rate (SR) was determined for each cycle based on maintaining pasture availability at similar levels between 400–800 kg/ha postgrazing (Table 1). As such, sheep SR varied between each cycle of grazing. Sheep grazed for 8 hours each day from 7.30 am until 3.30 pm, after which the sheep returned to the shed until the following morning. In the shed, sheep were provided with fresh water and mineral licks but no other supplements. Sheep were treated with anthelmintics at 6-week intervals to ensure that they were free from endoparasites.

### Measurements

Animals were weighed at 2-weekly intervals in the morning before they were sent out for grazing.

The CSIRO Botanal technique for estimating green dry matter (DM) yield and botanical composition (Tothill et al. 1992) was adopted for the first 9 harvests. Subsequently, DM was estimated by cutting samples from 0.5m<sup>2</sup> quadrats. Five quadrats

Table 1. Presentation dry matter yield of improved pasture under a hedgerow rubber system.

Draft	Treatment	DM(kg/ha)	
		Pregrazing	Postgrazing
1st draft	T1	990	780
Dec '92–July '93	T2	990	730
2nd draft	T1	1380	540
July '93–Mar '94	T2	1110	430

were cut for each sub-paddock of 0.06 ha. Species composition was determined by sorting the species manually.

## Results and Discussion

### Pasture yield and composition

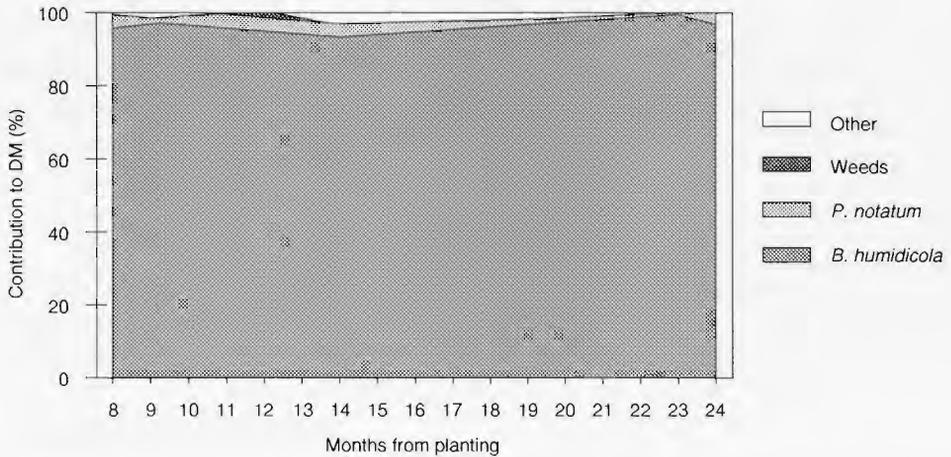
Pre- and postgrazing presentation yields did not vary significantly between treatments in the first draft, however the N-fertilised grass treatment (T1) had higher yields during the second draft (Table 1). Pastures were grazed down more heavily during the second draft in an attempt to reduce the frequency of ungrazed patches.

*B. humidicola* strongly dominated T1 throughout the experiment (Fig. 2a). *P. notatum* was very slow to establish and its long-term persistence did not appear promising.

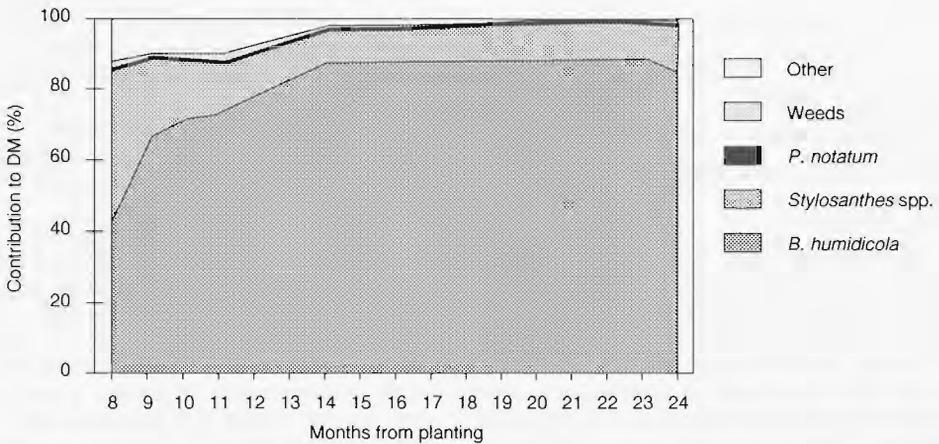
*B. humidicola* was the dominant species in the grass–legume treatment (T2) (> 44% contribution to DM), but *Stylosanthes* spp. also established strongly. Shade-tolerant species did not establish well (Fig. 2b). *P. notatum* was the most productive of the shade-tolerant species but contributed less than 3% to DM. At the commencement of grazing, a well balanced grass–legume mixture of *B. humidicola* and *S. guianensis* had established in T2. However, as grazing progressed, *B. humidicola* spread aggressively while the legume component in T2 declined dramatically. *Stylosanthes* spp. contribution to DM dropped from 45 to 9% from commencement of grazing to the end of the first 6-month grazing period. Contribution to DM improved to 13% with subsequent grazing. Both treatments effectively suppressed weeds throughout the experiment.

### Animal production

Liveweight production and stocking rate (SR) data are presented in Table 2. Two drafts of lambs were evaluated. T1 supported higher stocking rates than T2 throughout both drafts. However, whilst average daily gains (ADG) for T2 were consistently higher than T1 due to the legume component of the former treatment (Table 2), ADGs were well



**Figure 2a.** Botanical composition dynamics of the N-fertilised grass treatment following commencement of grazing.



**Figure 2b.** Botanical composition dynamics of the grass-legume treatment (T2) following commencement of grazing.

below those reported by Chong et al. (1995) for sheep grazing naturalised forages under rubber. Problems of patch grazing of *B. humidicola* based pastures have been reported elsewhere (Shui Chand, pers. comm.) and were only partially overcome by adjustment of grazing management in this experiment. Higher SRs using extra sheep were used initially to evenly graze paddocks, however problems arose early in the third draft with endoparasite build up and associated decline in animal performance (data not presented). Live-weight gain/ha was higher for T1 due to the higher sustainable SR.

**Table 2.** Sheep stocking rate (SR), average daily gains (ADG) and liveweight gain (LWG) of sheep grazing improved forages in double hedgerow rubber.

Draft no.	Treatment	SR (Lamb/ha)	ADG (g/lamb/day)	LWG (kg/ha/yr)
1	T1	36	51.0 <sup>a</sup>	670
	T2	29	63.3	670
2	T1	37	59.3 <sup>a</sup>	801
	T2	31	68.7	777

<sup>a</sup>Treatments not significantly different ( $P > 0.05$ ).

## Rubber growth

Girth measurements were taken when the trees were 2 and 2.5 years (Table 3). Average girth size did not vary between treatments at either sampling. The girth increments between the first and second samplings (4.0 cm for T1 and 4.2 cm for T2) were comparable to growth of conventionally spaced trees of the same clone and growing on similarly poor soils (class V for rubber).

Light transmission in the 20 m wide avenue between the double hedgerow rubber remained high over the sampling period (Table 3). Changes in light transmission conditions will be assessed over the next five years, however biomodelling work by Salleh (these proceedings) predicted that light transmission will remain above 58% for the life of the rubber.

**Table 3.** Girth and light transmission in hedgerow rubber system.

Treatment	Rubber girth (cm)		Light (% PAR <sup>a</sup> ) <sup>b</sup>	
	2 yrs	2.5 yrs	2 yrs	2.5 yrs
T1	14.4	18.4	88	84
T2	14.4	18.2	N.A.	86

<sup>a</sup>PAR=Photosynthetic Active Radiation

<sup>b</sup>Treatments not significantly different ( $P>0.05$ ).

## Economic considerations

The overall cost of planting the 'best-bet' mixture and the N-fertilised treatments was very high in comparison to conventional legume cover planting (Table 4). The high costs associated with the planting of pasture species from cuttings would limit the commercial use of these species. Fortunately the most successful species can be planted from seed and the use of mechanised planting equipment would lower establishment costs considerably.

**Table 4.** Cost of establishment, manuring and weeding for the hedgerow planted rubber (RM/ha).

Treatment	Establishment			Manuring			Weeding			Total cost		
	Plant matter	Labour	Total	Fertilizer	Labour	Total	Chemicals	Labour	Total	Materials	Labour	Total
1	126	173	299	495	42	536	28	652	679	648	867	1515
2	787	208	995	495	42	536	25	957	982	1302	1206	2514
Cover crop <sup>a</sup>	80	100	180	202	45	247	-	210	210	282	355	637

<sup>a</sup>Standard costs for planting conventional legume cover crops.

## Conclusions

*B. humidicola* formed a stable, weed-free pasture on the acid-infertile coarse sands at RRIES. *S. guianensis* associated productively with *B. humidicola* initially but with the commencement of grazing it did not persist. N-fertilised grass pastures sustained higher stocking rates and LWGs per unit area in comparison with grass-legume pastures. However, ADGs of sheep grazing grass-legume pasture were at best modest, due to the grazing management and sheep health problems associated with *B. humidicola*. These included a build-up of endoparasites and unpalatable rank patches within the pasture. These problems need to be addressed before *B. humidicola* can be recommended as a forage for sheep.

Growth of rubber, as determined by girth, did not differ between pasture treatments and was comparable to the growth of conventionally spaced rubber grown on similarly poor soils. Several more years of data are required to fully assess the interhedgerow light environment and pasture sustainability.

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# Biological Modelling of Rubber and Forage Productivity

Abd. Samat M.S. and H.M. Shelton\*

THE potential productivity of integrated rubber and sheep production will depend on the competitive interactions of the components which determine production. Production varies greatly according to the edaphoclimatic environment and the level of agronomic manipulation of growth factors. Some tradeoffs will occur in the attempt to provide optimum production conditions for both the rubber and forage components. Quantification of the many competitive and complementary variables at rubber-forage interface is expensive and time consuming. In an attempt to understand the interrelationships between these variables, development of a preliminary production model of the whole system is essential. Complex interacting processes and many possible management alternatives can be easily explored using a model without expensive field experimentation. Applications of the model can be wide ranging, from targetting research priorities, to assisting with management and extension decisions. This paper reports the development of an empirical biological model to predict potential yields of rubber and understory forages under varying spatial arrangements and densities of rubber.

## Model Development Methodology

Latex production from rubber can be estimated from a limited number of functions: girth, number of tappable trees, tappareability and yield per tapping per tree (Fig. 1). Studies of rubber growth at different densities by Ng (1993) and limited data from ongoing experiments on hedgerow planting at RRIM were used for extrapolation of rubber yield. Understorey forage production varies proportionately with light transmission through the rubber canopy. Light interception and light use efficiency of the understorey vegetation was extrapolated from a study by Sophanodora (1989).

Data for various factors affecting biological production were analysed by regression method. Relationships for variables were selected that produced equations of 'best fit' lines with minimum residual mean squares.

## Results and Discussion

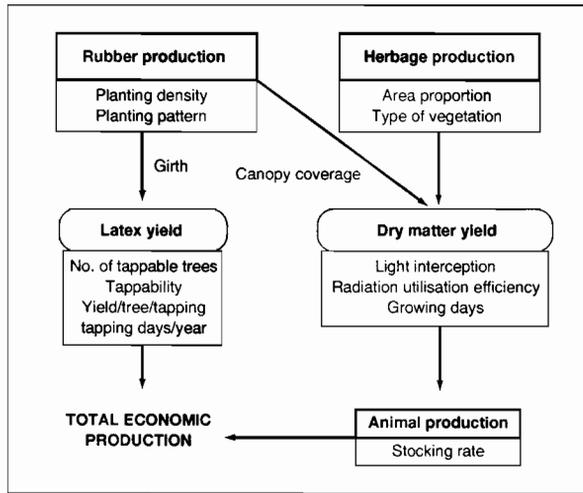
For the purpose of this paper, 4 densities of rubber trees were selected to examine the effect of rubber density on yield of rubber and forages. Trees were presumed to be planted in a conventional rectangular pattern. For comparison of spatial arrangement, the standard density of 400 rubber trees/ha was used. Conventionally spaced rubber was compared with a double hedgerow pattern. Densities and spatial arrangements are shown in Table 1.

## Simulated Rubber Growth and Production

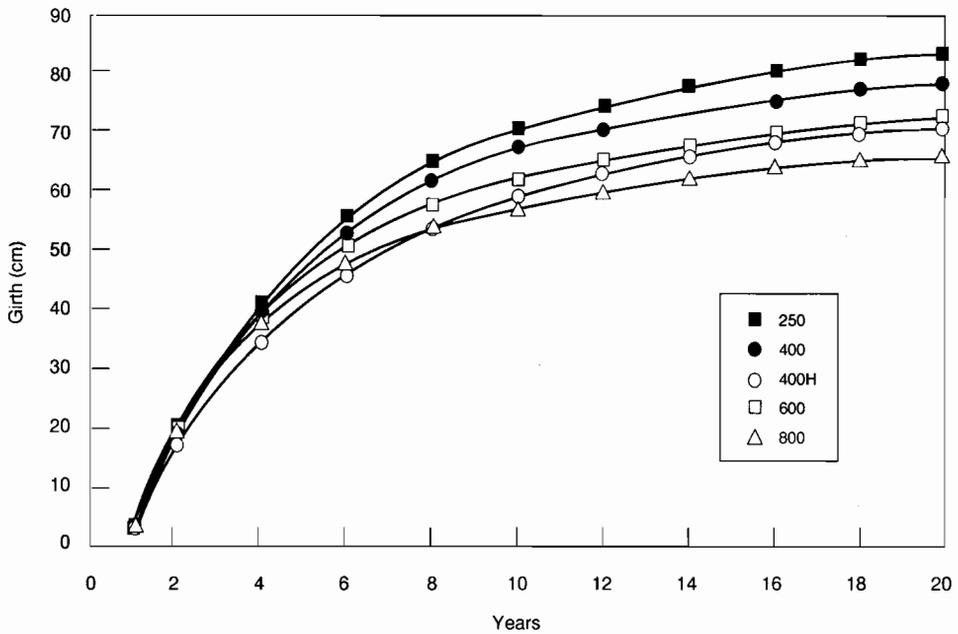
Tree densities affect tree growth (girth) and hence variation in planting density will increase or decrease the total rubber production. As a general rule, at higher tree densities latex production is high on a per unit area basis and lower on a per tree basis. The projected growth, as described by girth of rubber tree/ha at a given age, for four different planting densities is presented in Figure 2. At planting densities of 250, 400, 600 and 800 trees/ha, the trees will attain a mean trunk diameter or girth of 50 cm at 5, 5.25, 6 and 7 years of age respectively. Double hedgerow trees are comparatively slow growing attaining 50 cm girth at 7 years.

Latex yield is a function of the number of tappable trees and yield per tappable tree. The influence of planting density on the number of tappable trees and tappareability is described in Figures 3 and 4 respectively. The number of tappable trees increased with increasing density, however, beyond a certain point the number of tappable trees declined due to the high incidence of tree dryness at higher densities. At the low density little change was predicted. Lower planting densities gave higher percentage tappareability after opening for tapping, in comparison to higher densities where tappareability increased with time. The mean yield/tree/tapping, at all tapping panels, was estimated to correlate negatively to increasing density (Table 2). For double hedgerow plantings, yield functions were considered to be the same as for conventional plantings at 400 trees/ha, except that tapping started at later age when the mean girth reached 50 cm.

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**Figure 1.** Schematic diagram of the model's functional relationships.



**Figure 2.** Girth of rubber trees at different densities over time.

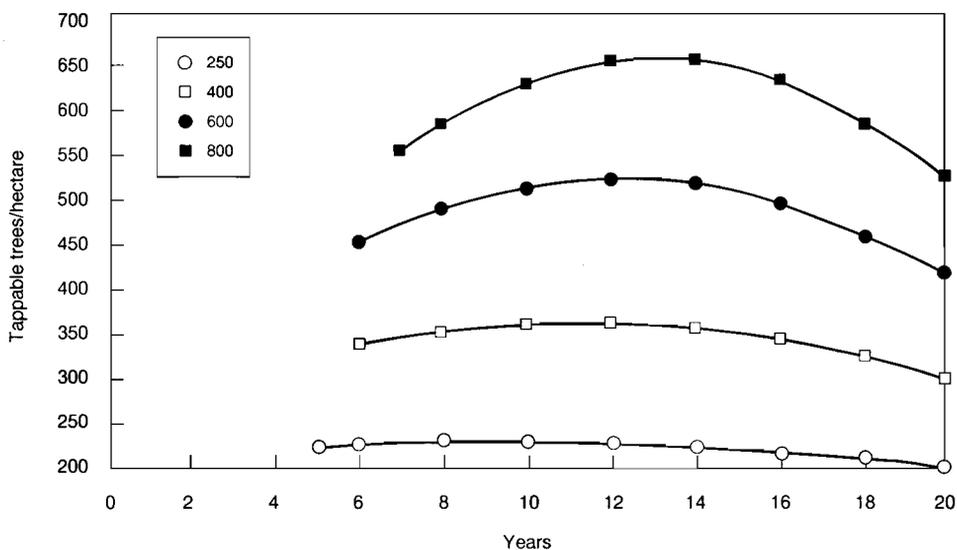


Figure 3. Number of tappable trees/ha at different rubber densities.

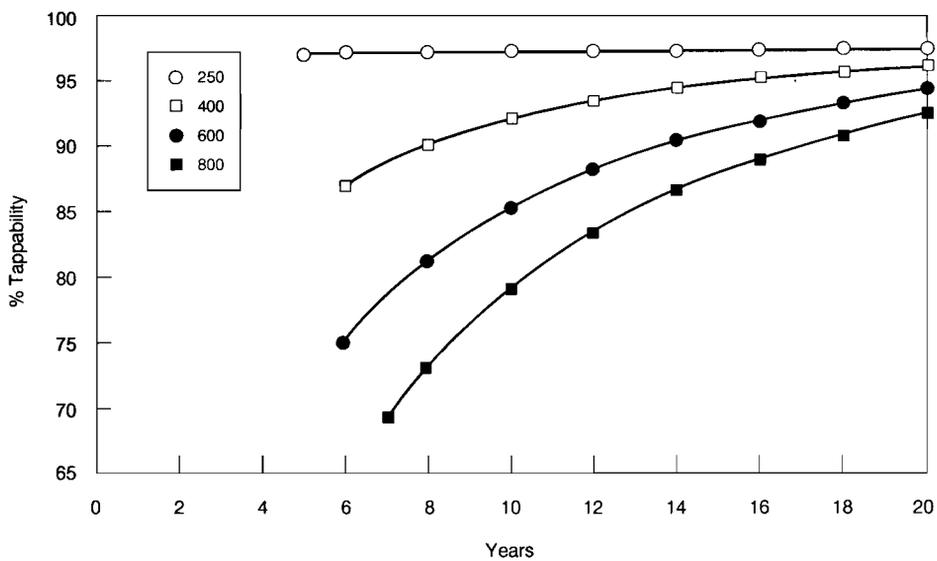


Figure 4. Percentage tappability at different rubber densities over time.

The yield/ha was based on the above function, assuming 150 tapping days/year. It was predicted that highest yields were achieved at high densities due to the high number of tappable trees/ha (Fig. 5), although percentage tappareability was projected to be lower than at the low densities. Figure 6 shows the simulated accumulated yield/ha at different densities and for the double hedgerow planting system. The lowest accumulated yield of 32 t was predicted for the double

hedgerow system. Densities of 800 and 600 trees/ha achieved the highest accumulated yields but yields at 400 and 250 trees/ha were only 3% lower.

## Simulated Forage Production

The interaction between the understorey vegetation and rubber may be positive or negative. Forage production under a tree plantation depends on the availability of light, nutrients and moisture, and types of vegetation present. Regardless of tree density or planting pattern, reduction of understorey production generally becomes evident temporally with the tree canopy development. Predicted time to total canopy coverage of a conventional rubber plantation in regular square or rectangular matrix was approximately 4.5, 6, 8 and 14 years for 800, 600, 400 and 250 trees/ha respectively (Fig. 7). The maximum canopy coverage in double hedgerow planting system of 400 trees/ha was only 45% of the alleyway area, approximately 6.5 m from each side of hedgerow.

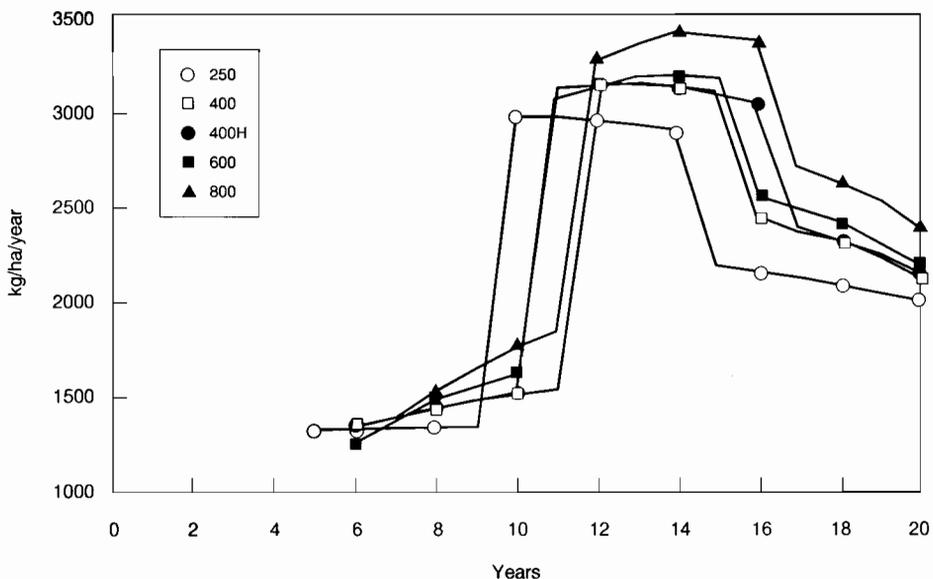
Light transmission through the tree canopy was estimated to be exponentially related to the canopy coverage of the area. The description of light transmission at various densities and planting patterns is shown in Figure 8. Rapid reduction of light transmission occurred during the first 5 years for all tree densities for the regular planting system. At densities of more than 400 trees/ha, final light transmission was predicted to be less than 30%. In the double hedgerow planting, a stable final light transmission of 58% was projected, becoming stable from year 6 onwards.

**Table 1.** Rubber tree planting density and patterns.

Trees/ha	Intrarow	Interrow 1	Interrow 2
250 Conventional	4 m	10 m	-
400 Conventional	4 m	6.25 m	-
400H Hedgerow	2 m	3 m	22 m
600 Conventional	3 m	5.6 m	-
800 Conventional	3 m	4.17 m	-

**Table 2.** Mean yield per tapping per tree at different planting density (g).

	Trees/ha			
	250	400	600	800
Panel B0-1	41	31	25	24
Panel B0-2	90	63	46	40
Panel B1-1	68	50	37	33



**Figure 5.** Rubber yield/ha at different densities over time.

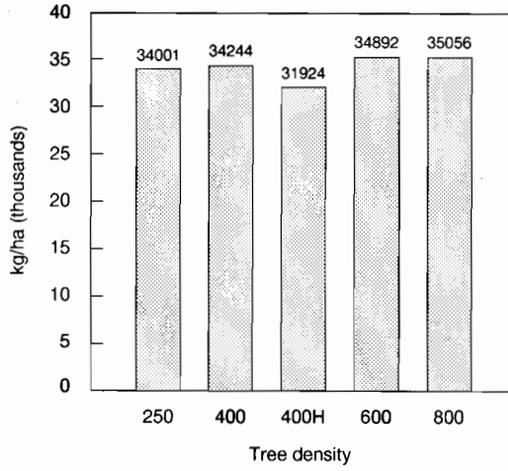


Figure 6. Accumulated rubber yield/ha at different densities and spatial arrangements.

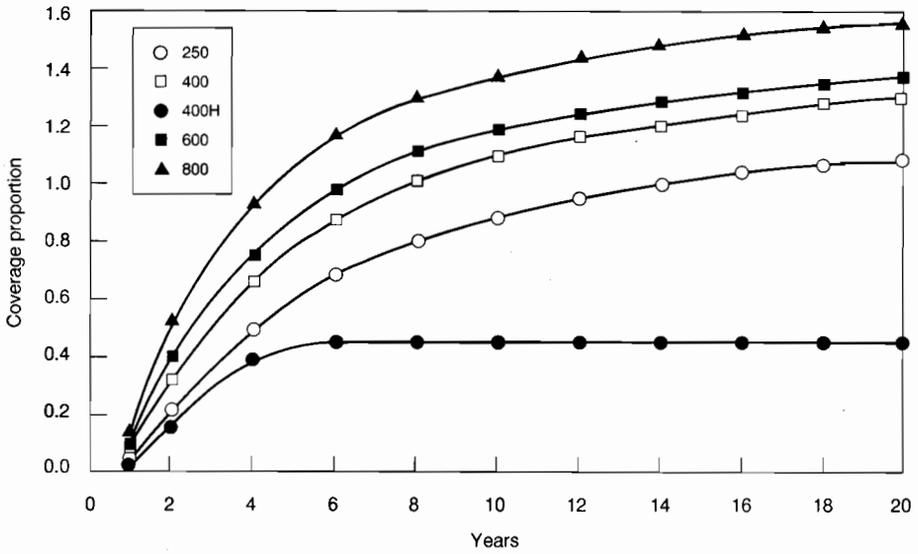


Figure 7. Changes in rubber tree canopy coverage at different densities and spatial arrangements over time.

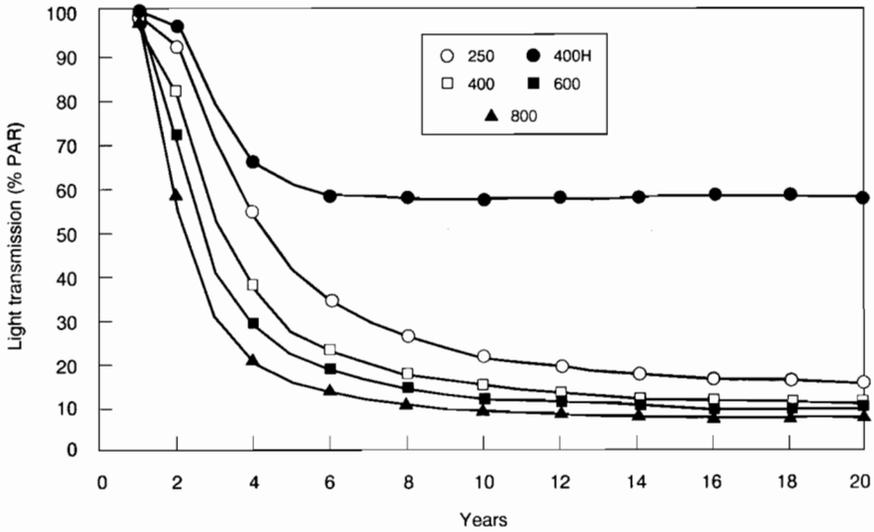


Figure 8. Light transmission under different rubber densities and spatial arrangements.

The simulated potential yields of natural vegetation under rubber at different densities and planting patterns are shown in Figure 9, based on the forage growth model suggested by Wilson and Ludlow (1991). Relative light interception by natural vegetation was assumed to be one-third that of improved pasture. At tree densities of 250, 600 and 800 trees/ha, the predicted total potential forage yield decreased from 9.5, 7.25 and 5.7 t/ha at year 2 to only 3.5, 1.2 and 0.7 t/ha at year 10 respectively. Higher tree densities had more dramatic impact on yield in

comparison to low densities. At 400 trees/ha in the double hedgerow planting, a forage yield of 6.1 t/ha was projected from year 10 onwards. The potential forage yield from improved pasture could be compared with natural vegetation in the two different planting systems only at 400 trees/ha. The simulated potential forage yield of improved pasture was three times that of the natural vegetation (Fig. 10). Despite higher improved pasture yield compared with native forage yield for conventional planting layouts, yields of both pastures declined dramatically by year 6.

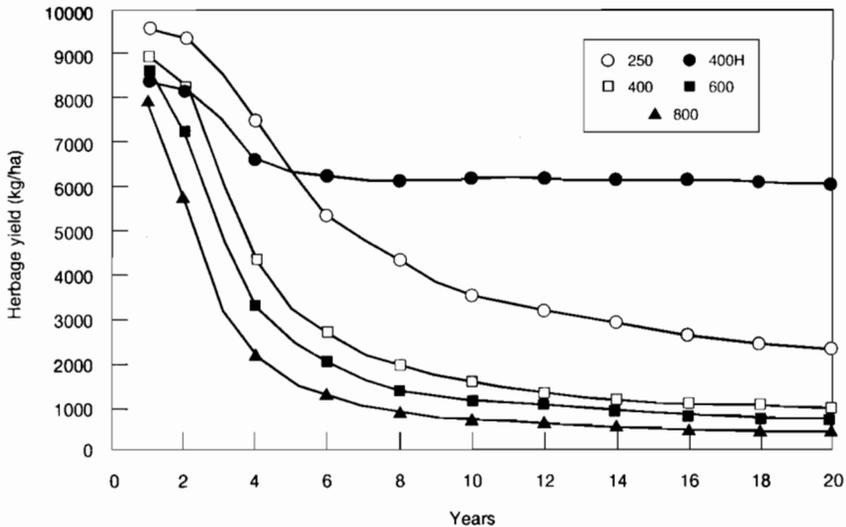
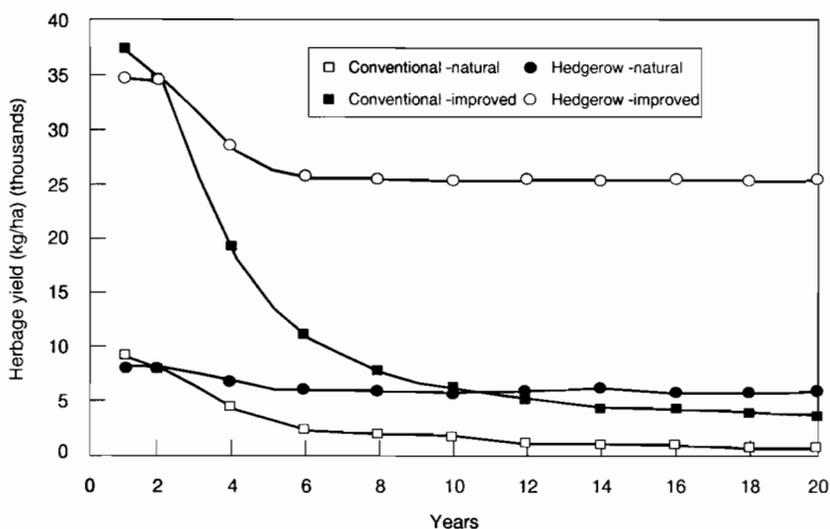


Figure 9. Dry matter yields of natural vegetation under different rubber densities over time.



**Figure 10.** Forage yields of natural and improved pastures under the same rubber density (400 plants/ha) but with different spatial arrangements (conventional compared with hedgerow).

## Conclusions

The potential effects of varying the spatial arrangement of rubber trees and other management practices were illustrated by a series of simulations of the model. Rapid analysis of the tradeoffs involved was possible and results could be presented in a simple and straightforward manner. Relationships indicated by the simulations suggested an underlying regularity in terms of cause and effect between management practice and productivity of the system. The model significantly enhanced our ability to determine likely productivity of the system under a given set of conditions. The stability of climatic conditions at the study site was a definite advantage in that climatic variables could be excluded from the model. However, a full

description of the interactions involved in the whole system is beyond the scope of this study model. A key feature of future work will be the calibration and validation of the various functions of the model.

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## **Forages Extension**

# Livestock Extension Linkages in Bali

I.K. Rika\*

LIVESTOCK are an integral part of Balinese farming systems and the sector has strengthened steadily over the past ten years. Despite the bright prospects of the livestock sector in Bali, productivity of smallholder cattle is low. Livestock extension organisations are working to develop a range of programs addressing husbandry, management, production and marketing. The Directorate General Livestock Services (DGLS) is the dominant livestock extension organisation, however the universities are also involved in extension. This paper outlines the linkages between Balinese farmers and these organisations.

## Directorate General Livestock Services (DGLS)

The DGLS organisational structure is summarised by Siagian and Tuhulele (these proceedings). Whilst the formal structure of extension services is decided at a national level, the provincial Livestock Services (LS) (Dinas Peternakan) largely decide their own priorities. Priorities for extension activities are developed through annual consultations with regency and district leaders and Dinas Peternakan staff. Regency (8 regencies in Bali) and district leaders obtain their information from village headmen, farmer group leaders and individual farmers. Provincial LS leaders then develop integrated programs using the resources of the regency and district LS, and the University Faculty of Animal Husbandry. Finances for LS extension activities are allocated following these meetings and the various leaders report back to their constituents. Submissions may be made to the provincial government through LS from the University for specific extension activities. For example, in 1994 the University Udayana Faculty of Animal Husbandry submitted to LS a proposal to establish pasture species nurseries at two sites in central southern Bali.

Regency and district LS extension are reviewed by Siagian and Tuhulele (these proceedings) and will therefore not be covered by this paper.

## University Extension

Within each university, a Department of Extension Services (DES) exists with the responsibility for extending technologies generated from within the university. The DES performs routine extension activities targeted at both students and farmer groups. Senior staff from various faculties within the university may be funded by DES to undertake specific extension activities.

A major university extension activity occurs by way of the KKN student placings, undertaken by third and fourth year students as part of their final year program. Students work in selected villages for a two-month period to improve their practical skills. Poorer villages with potential for development are selected. Fifty-eight KKN student groups worked throughout Bali in 1994 and 25% of these villages had specific potential for cattle development. Students established nurseries of selected forages in cooperation with village farmer groups. Contacts with district Dinas Peternakan are also established.

## DGLS-University Collaboration

Close linkages are formed between the LS and the University DES (Fig. 1). Technology ownership remains initially with the identifying organisation, however the LS have the best developed infrastructure through which to disseminate information. LS are informed of DES livestock extension activities and are commonly invited to participate. LS may embrace and develop technologies being extended by the University. For example, the DES recently supported the University Faculty of Animal Husbandry in a program to extend ACIAR Forages for Plantation Crops technology. Funds were allocated to host field days, and to establish demonstration plots. DES then approached the provincial LS for further financial and practical support. In addition to this support, the LS agreed to continue the forages development work after 1995.

## Farmer Groups

At a village level, farmer groups were formed following a DGLS initiative commencing in 1984 (Sia-

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gian and Tuhulele, these proceedings). There may be several farmer groups within each village specific to particular agricultural commodities. Within the livestock sector, separate farmer groups have been formed to cover cattle and large animals, pigs, poultry and goats. Within each group a leader is elected. These leaders then liaise with the village headman (*kepala desa*) to discuss new ideas and to address agricultural issues that require action. Leader farmers are particularly important within the agricultural community, as they have the authority to vet or reject new technologies.

Both the LS and the University DES work closely with leader farmers in developing technologies. The DES have chosen three villages in which to develop ACIAR forages. Leader farmers in these villages are supported both financially and technically in on-farm testing of forages. The LS have attended University field days on these farms.

Through close cooperation between the University DES and the provincial LS, maximum benefits of University research and the provincial LS extension network can be realised. Undergraduate university students gain valuable practical experience through the KKN field work.

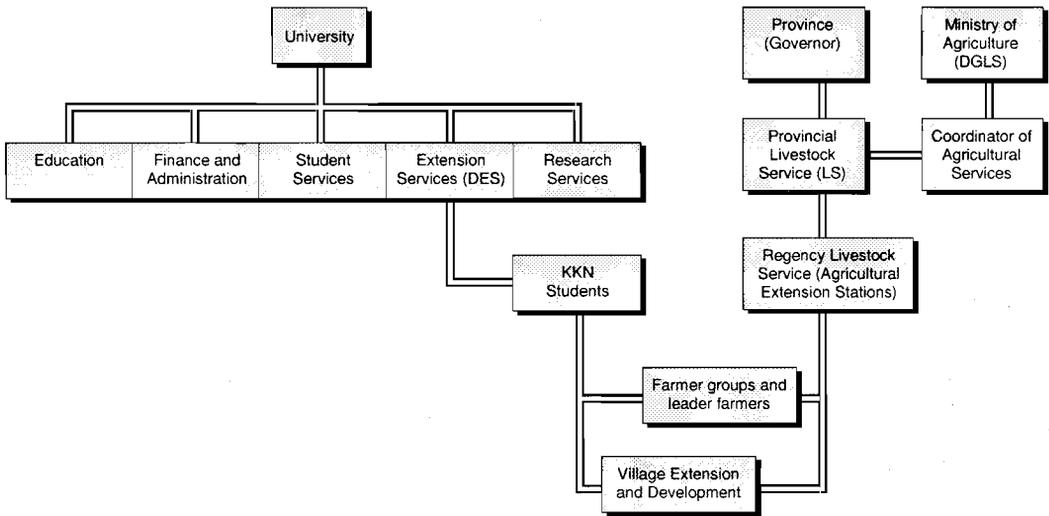


Figure 1. Agricultural extension channels and linkages in Bali.

# Forages Extension in Malaysia

Tajuddin Ismail and Chong Dai Thai\*

THERE are 2.1 million hectares of oil palm and 1.8 million hectares of rubber in Malaysia with potential to integrate ruminant animals to provide secondary income. Naturalised undergrowth of these plantation crops comprises grasses and broadleaved species of which a major proportion are palatable to both sheep and cattle. During the last decade, rubber and oil palm growers have been encouraged to integrate ruminants into plantations to maximise land use, reduce the use of herbicides and cost of weed control and diversify income. However, only a very small proportion of plantations have adopted this new technology and very little of the available forages are utilised for ruminant production.

Improved forages are confined to state farms, Department of Veterinary Services (DVS) farms and Malaysian Agricultural Research and Development Institute (MARDI) research stations. In the case of smallholders, only dairy cattle farmers cultivate improved forages such as *Panicum maximum*, *Pennisetum purpureum* and *Leucaena leucocephala* under cut-and-carry systems. Very rarely are improved forages used in plantations.

A major constraint to the development of ruminant integration in plantations has been the poor animal productivity achieved from naturalised forages. It is our current thinking that we need to introduce improved forages in plantations to increase and sustain forage supply so that animal productivity could be substantially increased. To overcome this problem, a range of improved forages are currently being evaluated under various plantation crop spatial arrangements. Increases in forage yield and quality and long-term sustainability of yield are the first requirements for a productive and profitable forage-animal-tree crop system. Research carried out by MARDI and Rubber Research Institute of Malaysia (RRIM) failed to identify forages that could persist productively under mature rubber and oil palm. An alternative spatial arrangement for rubber trees is being investigated by RRIM and whilst early results are encouraging, no recommendations can be made

as yet. It is therefore not surprising that only minimal resources are expended on extension of forages technologies for plantation crops in Malaysia. Research-industry links are strong however, and larger plantations and estates are regularly updated as to research outputs. Final stage research commonly involves on-farm pilot projects where plantation managers have direct input into technology development. This paper outlines the practical activities carried out by Malaysian Government departments to promote the usage of improved forages for ruminants in plantation crops.

## DVS Extension Program on Forages

The Department of Veterinary Services (DVS) is the only agency responsible for promoting the use of improved forages. Under their forage extension program, DVS allocates approximately US\$60000 per year in the form of subsidies to help farmers develop homeplots (pasture/fodder banks). Farmers are given seeds/cuttings, fencing materials and service for land preparation. The DVS also distributes polybag plants of fodder tree species of *L. leucocephala*, *Acacia mangium* and local species of 'Ludai' and 'Kesainai'. In 1993, DVS distributed about 10000 kg seeds of the following species: *Brachiaria decumbens*, *Brachiaria humidicola*, *Brachiaria ruziziensis*, *Panicum maximum*, *Setaria sphacelata*, *Desmodium ovalifolium*, *Centrosema pubescens*, and *Stylosanthes* spp.

Plant cuttings of *P. purpureum* and *Digitaria setivalva* are also distributed to smallholders (DVS 1994, unpublished data).

## Research on Improved Forages in Plantations

MARDI has conducted extensive research on performance of improved forages under oil palm. Chen and Bong Julita (1993) concluded that none of the improved forages evaluated was persistent under the palm canopy. RRIM (1985, unpublished data) evaluated *P. maximum* cv. Vencidor for utilisation under rubber and found that the species did not persist under the canopy of maturing rubber. Collaborative

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research work by ACIAR and RRIM (ACIAR Project No. 8560) evaluated 90 introduced and local forage species of grass and legumes under immature rubber. None of these species persisted well when light fell below 20% Photosynthetic Active Radiation (PAR). (Ng 1991). Under the present ACIAR Project No. 9113, selected forage species are being evaluated under a double hedgerow rubber planting system. A significant special feature of the double hedgerow planting system is that the interrows are 22 m wide compared to only 9 m or less in the conventional planting system. The wide interrows allow for long-term, high-light penetration that will enable continuous and sustainable forage growth even during the mature phase of rubber. Through this system, animal productivity is expected to be sustained at higher levels in the longer term.

Evaluation of forages and sheep productivity using 3 spatial arrangements (triangular, single-row and double-row) of oil palm was initiated by MARDI and PORIM in 1986. Early results indicate that the double-row spatial arrangement has potential for sheep production especially during the later years when the oil palm canopy starts to close and light becomes limiting to the growth of forage species (Eng 1992).

## Proposed Forages Extension Program

From RRIM research, an alternative plantation system has been developed that is suitable for the commercial production of sheep or other secondary products. This is in contrast with the present situation, where the animals are forced to fit into the conventional plantation environment.

A proposed program has been developed based on the limited data available. The program will be implemented as a packaged technology that involves the introduction of the new planting arrangement and cover crop policies, coupled with adoption of the latest technologies in rubber, forage, and animal management practices. Modifications and adjustments should be made as more information becomes available. Brief details of the proposal for monitored pilot development projects are as follows.

- Site: Government land development schemes due for replanting e.g. in FELCRA.
- No. of schemes and area: Maximum of 3 schemes of 40 ha/scheme.

- Planting system of rubber: Double hedgerow planting system : 22 m × (3 m × 2 m).
- Forage species and establishment method: *Brachiaria humidicola* + *Stylosanthes* spp.; Rotovate soil and broadcast seeds.
- Grazing management: Early grazing (3 months after forage establishment); Mob grazing at 6–8 week intervals.
- Manuring of rubber and forages: Rubber — As recommended practice; Forages — Sheep dung twice a year + NPK Mg at 3-monthly intervals.
- Fencing: 1–2 ha per paddock.
- Sheep: Dorset × Malin crossbred, 200 ewes + 10 rams per scheme.
- Assessment: (a) Forage production; (b) Sheep production; (c) Rubber growth and yield; (d) Savings in cost of weed control; (e) Overall economics of the technology
- Officials involved: a. Technical officers of FELCRA; b. Research officers of RRIM; c. Manager of schemes; d. Field supervisors; e. Local veterinarians.

## Conclusion

Forages extension in Malaysia occurs at two levels. Firstly, through the activities of DVS in promoting improved forages to smallholders, and secondly through the pilot schemes of research institutions such as RRIM. Further extension thrusts will depend on the identification of suitable forages and production systems for ruminant integration into plantation crops.

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# Extension of CIAT Research in Southeast Asia

W.W. Stür\*

THE International Center for Tropical Agriculture (CIAT) is a development-oriented, agricultural research institution under the auspices of the Consultative Group on International Agricultural Research (CGIAR). It was established in 1969, and is working on germplasm development of beans, rice, cassava and forages, and conducts resource management research on hillsides, forest margins, savannas, and land use. Its headquarters are in Cali, Colombia.

For more than two decades, CIAT has worked on improvement of tropical forages for use in tropical America. Many million hectares of pastures are now grown in South and Central America. Although farming systems in tropical America are quite different from those in Southeast Asia, there are many similarities with regard to soils (acid, infertile) and climate (Fig. 1). It is therefore likely that many of the successful forage varieties developed in tropical America will be useful forages in Southeast Asia. CIAT has been looking for an opportunity to establish a base in Southeast Asia, and such an opportunity arose when the Australian International Development Assistance Bureau (AIDAB) agreed to fund a joint CIAT/CSIRO (Commonwealth Scientific Industrial Research Organisation of Australia) proposal for a regional 'Forage Seeds Project' (FSP) from January 1992 to December 1994.

## Forage Seeds Project (January 1992 to December 1994)

The FSP brought together the germplasm resources of the Genetic Resource Center of CIAT and the Australian Tropical Forages Genetic Resources Centre (ATFGRC), CSIRO Division of Tropical Crops and Pastures. These two collections complement each other with CIAT's emphasis on acid, infertile soils of the humid and sub-humid tropics, and ATFGRC's emphasis on tropical and subtropical areas with an extended dry season. The combined germplasm resources of these two centres cover most of the climatic and soil conditions of Southeast Asia.

The aim of the project was to assist the governments of Indonesia, Malaysia, the Philippines and Thailand to increase animal production through the introduction of appropriate varieties of forage species in smallholder farming systems.

The project has worked collaboratively with Recipient Government (RG) partners within the organisational framework of the various countries. The approach was regional, linking the various RG partners through annual meetings and information exchange. Linkages were also developed with national and international extension and development agencies to ensure that the results of the project were made available to farmers in other areas. Emphasis was placed on practical training in Australia, the Philippines and in-country.

Briefly, the following outputs were produced:

- (i) Over 400 forage accessions were introduced to the region. These were screened for pest and disease resistance at the central screening site in the Philippines. Seed of the 40 most promising varieties was produced and these, together with promising varieties from Australia, were supplied to RG collaborators for regional evaluation.
- (ii) As a result of regional evaluation, adapted forage cultivars were identified, and seed or vegetative material of these cultivars was produced for on-farm evaluation by RG collaborators and other extension and development agencies. In total, more than 3000 packets of seed were distributed. Additionally, large quantities of vegetative planting material was supplied for on-farm work, extension and development activities.
- (iii) As a result of regional evaluation and on-farm evaluations, six widely adapted forage cultivars were identified for different agroecological zones and these were recommended for release in Southeast Asia. These were *Andropogon gayanus* cv. Kent and CIAT 621, *Brachiaria brizantha* CIAT 6780, *Brachiaria decumbens* cv. Basilisk (= CIAT 606), *Brachiaria humidicola* cv. Tully, CIAT 6369, CIAT 16886 and CIAT 6133 (often referred to as *B. dictyonera*), *Centrosema pubescens* CIAT 15160, and

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*Stylosanthes guianensis* CIAT 184. Field days were held in project locations and these were attended by more than 400 farmers. They received some basic training in how to plant and manage forages, and most farmers requested and received seed or vegetative planting material for evaluation on their own farm. Follow up with collaborating farmers showed that several farmers had extended the area of planted forages on their own initiative, saying that the forages were productive, their animals liked the new forages and that animal production was high when feeding these forages. Seed production of the recommended species has begun on government stations and in smallholder pilot seed production schemes with the first successful harvests in 1994. This seed has been distributed to other smallholder farmers.

- (iv) Results of evaluations, forage germplasm and ideas on how to make the recommended forages available to smallholder farmers were freely exchanged between RG collaborators and other extension and development agencies.
- (v) Personnel in collaborating agencies were trained in forage evaluation techniques and seed production. Collaborating agencies in Indonesia and the Philippines financed in-country training courses for additional staff based on the training that collaborators received in Australia.

The project was successful in identifying adapted forages, particularly for the more acid-infertile soils of the region. A proposal for a second five-year project was developed to promote the evaluation and adoption of these introduced species by farmers into farming systems and to extend activities into Lao PDR, Vietnam and Southern China.

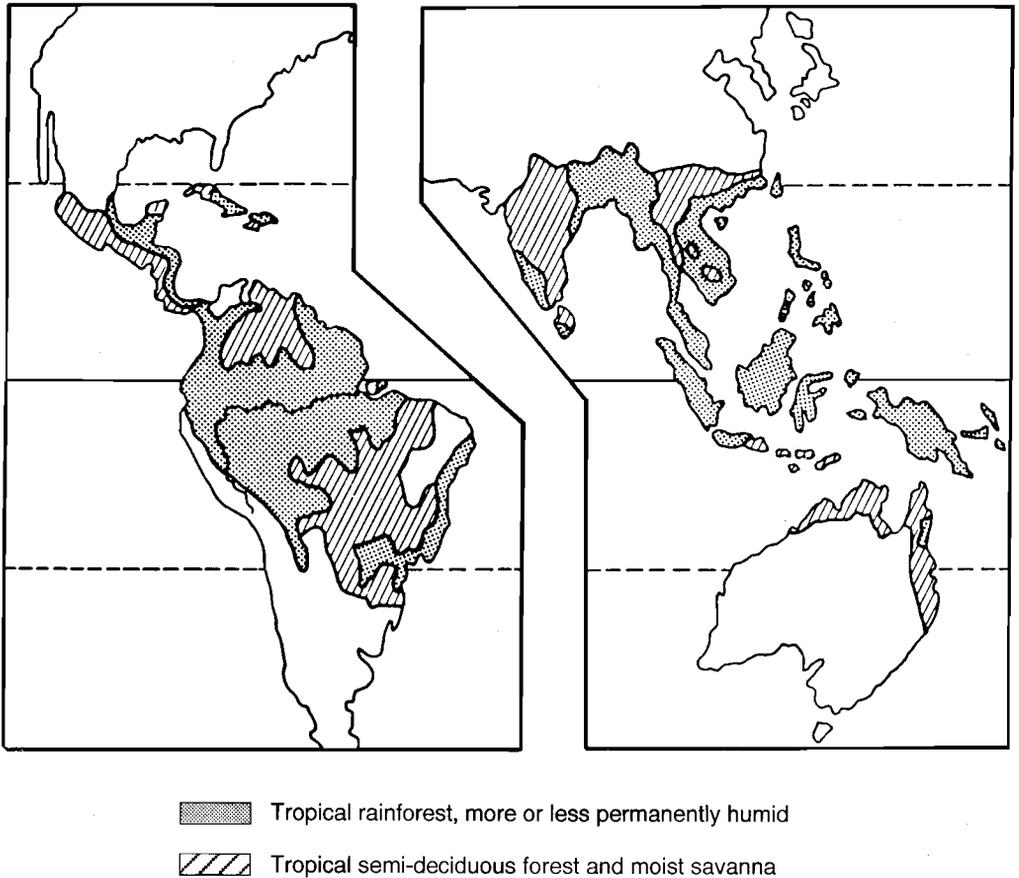


Figure 1. Comparing the climate of Latin America with Southeast Asia.

## Forages for Smallholders Project (January 1995 to December 1999)

The purpose of the Project is to increase the availability of adapted forages and the capacity to deliver them to appropriate farming systems, in particular, agroforestry and other upland systems.

The objectives to achieve this are:

- (i) To identify forages for different ecoregions in agroforestry, upland cropping and plantation systems,
- (ii) To integrate forages into these different farming systems through participatory research and development (R&D),
- (iii) To increase the capability of national staff through training, and
- (iv) To improve the effectiveness of the regional R&D activities through networking.

The project will work within the organisational framework of collaborating countries, working in partnership with them and supporting national staff. Emphasis will be placed on integrating forages into smallholder farming systems and developing delivery systems to ensure that adapted forages are widely

available to farmers. There will be a large training component which will concentrate on practical aspects. The project will support farmer field-days and training, and actively involve farmers in the selection of forages through participatory research. Countries involved in the project will be Lao, Vietnam, Philippines, Indonesia, Thailand, Malaysia and South China.

A five-year time frame is proposed because of the successive steps and magnitude of training in new methodology, that need to be undertaken in order to ensure adoption of not only new forages but new forage systems.

The linkages and interactions between activities of the Project are shown in Figure 2.

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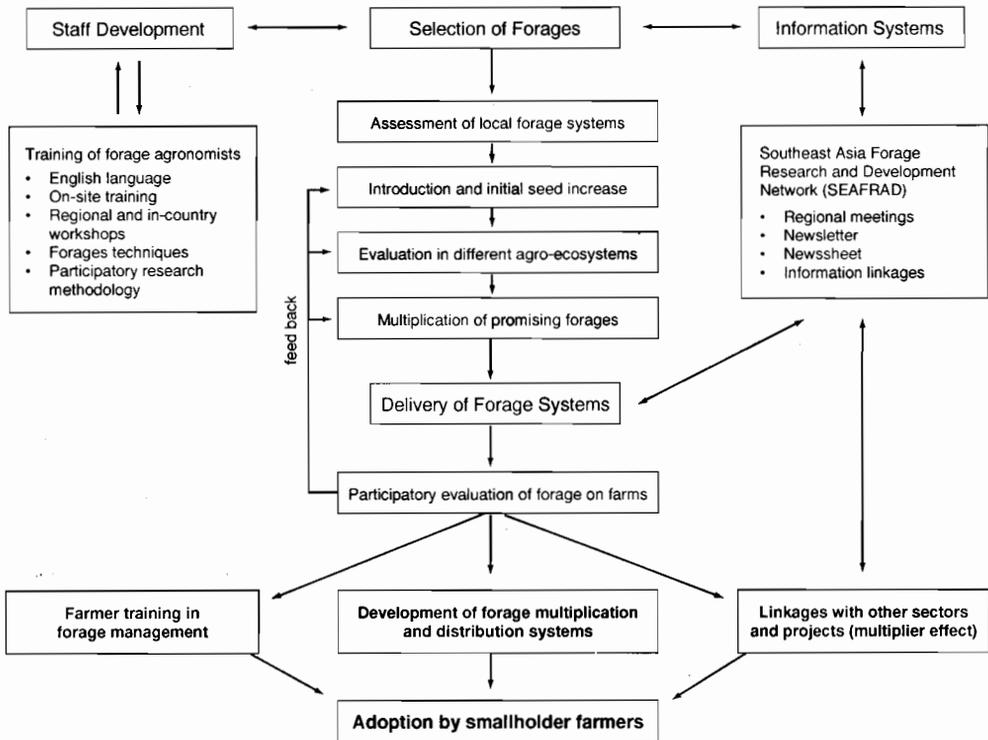


Figure 2. Linkages and interactions between project activities (Source: Toledo 1986).

# The Structure of Government Livestock Extension in Indonesia

H. Siagian and Maimunah Tuhulele\*

LIVESTOCK extension plays an important role in achieving the objectives of livestock development in Indonesia. Agriculture extension activities are implemented by the Directorate General of Livestock Services (DGLS) following the policies of the Ministry of Agriculture. The Research and Extension Linkage model (REL) of technology transfer is basic to agricultural extension policy.

Livestock development in Indonesia is aimed at creating a progressive, efficient, and strong livestock subsector, characterised by the ability to:

- meet population demand;
- adjust the pattern and structure of production to meet market demands;
- have a share in regional development;
- create job opportunities;
- increase farmers' income and welfare, and;
- participate in environment betterment and economic growth.

In achieving these aims, the livestock sector should be regarded as a biological industry, controlled by human beings, and consisting of:

1. The farmer, as the subject of development, his income and welfare should be increased.
2. The livestock, as the object of development, production and productivity should be increased.
3. Land and environment, as the basis of farming and ecological management; the potential of the land to supply food products should be increased without degradation of the environment.
4. Technology, as the tool to achieve these goals.

Based on these concepts, development of human resources has become the top priority. Upgrading of farmer skills will be achieved through improved farmer access to information, capital, science and technology leading to increased efficiency and productivity.

Various problems limit the achievements of DGLS extension activities. These include: the limited number of Agricultural Extension Stations (BPP); the limited number and technical abilities of extension workers; and the limited facilities at their disposal, (eg. transportation facilities). This paper outlines the structure of the Government livestock extension activities in Indonesia.

## The Development of Livestock Extension in Indonesia

Livestock extension has been carried out informally since PELITA (Five Year Development Stage) I and II when livestock was not considered to be of high priority. Formal livestock extension activities began with the establishment of Directorate of Livestock Extension in 1971. Livestock extension has undergone many changes since that time, but steady growth has occurred since 1979 (Table 1).

**Table 1.** Growth of the livestock extension service.

	1979	1984	1989	1994
Specialised extension workers (PPS)	14	132	203	516
Field extension workers (PPL)	23	423	2318	5082
Farmer groups	-	4838	11005	45791
Agricultural extension station (BPP)	-	193	273	252

During the Fifth Five Year Development Stage (PELITA V, 1989–1994) the GDP of the livestock subsector increased at a rate of 3.64% per year. This was higher than the increase in the total agriculture sector (3.24%), but lower than the increase in national GDP (6.84%). The importance of livestock

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production to the national GDP diminished over the period, from 2.09% in 1989 to 1.91% in 1992. Within the agricultural sector, livestock production has increased its contribution to the sectors GDP from 10.7% in 1989 to 10.84% in 1992 (Rancangan Repelita VI Peternakan, Direktorat Jenderal Peternakan). These figures highlight the success of livestock development programs over the period during a time of rapid industrial expansion.

## **Agriculture Extension Policy and Its Implementation in Livestock Extension**

Extension activities are implemented subject to existing Government policies and regulations. Activities aim to improve the knowledge, skills, and attitudes of farmers by supporting various programs of agricultural development. Agricultural policy is guided by the 'Joint Decree of the Minister of Home Affairs and the Minister of Agriculture of 1991'. Under this Decree a range of agricultural (including livestock) extension policies were established.

### **Mechanisms of Agriculture Extension Activities**

At a national level, the responsibility for the activities of agriculture extension lies with the Minister of Agriculture, and is carried out by the Head of the Center of Agriculture Extension (Table 2). Administratively, the Head of the Center is under the guidance of the Secretary General, and technically, under the guidance of the respective Directorate General (Food Crops, Livestock, etc.).

At a provincial level, the responsibility lies with the Governors of the respective provinces. Technical guidance is conducted by the Kepala Kantor Wilayah Departemen Pertanian (Kakanwil Deptan/Head of the Regional Office of the Ministry of Agriculture), who monitors and evaluates the extension activities in the respective provinces, and acts as a liaison officer for the Ministry of Agriculture.

At the district level, the responsibility lies with the Bupati (Head of the District). A task force is responsible for the implementation of the extension activities, under technical guidance from the Kakanwil, in coordination with the Bupati, Head of the Dinas Tk. II (District Office of Agriculture Sub-sectors), and other related offices. The Head of the District Dinas assists the Bupati, in coordination with the Agriculture Task Force of the District, in carrying out the extension activities. Agricultural Extension Stations (BPP) support the extension activities. The Livestock Field Extension Workers (PPL) stationed in their working areas are responsible to the Head of the Dinas Peternakan of the District (Table 2).

### **Agriculture Extension Stations (BPP)**

The BPPs function as supporting facilities for agriculture extension activities (including livestock extension activities). In carrying out this function, BPPs conduct activities such as:

- Agricultural training and skills development for farmers, especially contact/key farmers and village and public leaders;
- Training of the extension workers;
- Relaying agricultural information to farmers;
- Preparing recommendations on appropriate farming technologies; and
- Setting up demonstration plots, farmer discussion groups and village libraries.

BPP is under the administration of the Dinas of the locally dominant subsector. Whenever a BPP is not available in a certain location, the extension activities can make use of the existing UPP Perkebunan (Estate Crops Project Service Units), Poskeswan (Animal Health Posts) and Pos IB (Artificial Insemination Posts). Two-hundred-and-three livestock BPPs currently function in 154 districts, while 145 districts have no BPP for livestock.

### **Working Territory of Agriculture Extension (WKPP)**

A WKPP is a working territory of one PPL, set up in such a way so that all the development activities and programs in each WKPP are able to be handled by a single PPL. Each WKPP manages approximately 16 farmer groups, regardless of the number of villages in the district.

There are currently 5082 WKPP units for livestock, an insufficient number when the extent of Indonesian livestock sector and the number of farmer households are considered. The ratio of extension workers to the number of villages is 1:12, hence most of the PPL work in large WKPP, some to the extent of one per entire subdistrict.

### **Agricultural extension workers (PPL and PPS)**

The agricultural extension workers are functional personnel who conduct field extension activities and have direct contact with farmers. They are grouped into:

#### *Non-degree extension workers (PPL)*

The PPLs are assigned to assist the district government (the Dinas) and are stationed at WKPP. In theory each PPL, equipped with complete operational facilities, leads 16 farmer groups through a 'training and visit scheme', however, in practice, the number of farmer groups is adjusted to suit the condition of the WKPP. Only 36% of PPLs have animal science backgrounds and only 13.7% are equipped with motor bikes. The PPLs are responsible to the Head of the Dinas at the district level, or the Head of the Dinas at subdistrict level.

**Table 2. Agriculture extension responsibilities at different levels of government.**

Level	Central government			Local government			Extension institutions	
	Ministry of Agriculture	Director General of Livestock Services	Head of the Agency for Agriculture Training and Education	Head of Regional Agriculture Office	Governor of the Province	Head of Provincial Livestock Services		Head of District (Bupati)
National	Responsible for the implementation of national agriculture extension	Technical guidance	Training and education of extension workers	-	-	-	-	-
Province	-	-	-	Technical guidance monitoring evaluation	Responsible for the implementation of regional agriculture extension	Assisting the governor in the implementation of regional agricultural extension supported by the provincial PPS	-	PPS
District	-	-	-	-	-	Responsible for the implementation of regional agriculture extension at district level	Assisting the Bupati in the implementation of extension activities supported by district PPS	PPS
Sub-district	-	-	-	-	-	-	Supporting agricultural extension	PPL WKPP Farmer groups
Village	-	-	-	-	-	-	-	PPL WKPP Farmer groups

### *Graduate extension workers (PPS)*

- (i) The PPS stationed at the district level conduct extension programs and supervise extension activities in the district. The PPSs also function as a support base for the extension workers in the WKPP.
- (ii) The PPS stationed at the provincial level prepare and conduct extension activity programs and monitor extension activities around the province. They also act as support for the extension workers at district level. Of the 516 PPS, most are animal science graduates.

### **Farmers institution/farmer groups**

Farmer groups have been established based on commonality of needs and socioeconomic conditions and the strength of the relationships amongst the members. Farmer groups have a minimum membership of 20 and a maximum number determined according to the type of farming or local conditions. The number of livestock farmer groups at present is 45791, grouped into 4 categories: beginners (45%); intermediate (30%); post-intermediate (20%); and advanced (5%). The Contact Farmer is the administrator of a farmer group and is chosen by the group members. The Model Contact Farmer (KTNA) is a dependable contact farmer, chosen periodically by the contact farmers in a village. There may be more than one KTNA in each village.

## **Methods of Extension**

A range of extension methods are employed to deliver livestock sector information to farmers including, personal contact with the farmers, use of electronic media (television, radio, video and slide projector) and use of printed media (brochure, leaflet, folder). Extension worker contact with farmers may be via (a) individual contact—the extension workers approach the target farmers individually, either directly or indirectly, by means of home or farm visits, personal correspondence or phone calls; (b) group contact—the extension workers approach targetted farmer groups by means of meetings (training and visit), demonstrations, group discussions, field trips or training courses; or (c) mass contact—the extension workers deliver their messages to a number of targets simultaneously, by means of mass meetings, radio broadcastings, cultural events, distribution of posters and pamphlets or film shows.

## **Research and Extension Linkages (REL)**

Transfer of technology is conducted based on the principle of the 'Research and Extension Linkage

MODEL' (REL), where the research institutions are the source of technology, and the extension workers deliver/transfer the technology to the farmers. A Decree of the Minister of Agriculture describes the responsibilities of the various stakeholders within the agricultural sector. These are summarised below.

### **Research agencies**

- Determine development strategy of the region,
- Determine the master plan of regional development, together with the extension workers, the region administrators, and the private sector,
- Determine the technology packages for regional development, and
- Receive feedback information from the farmers.

### **Livestock extension workers**

- Identify regional problems;
- Prepare extension programs;
- Conduct tests and experiments on new technologies;
- Intercept feedback information from farmers and pass it onto research agencies; and
- Attend demonstration and training activities

### **District authorities**

- Use technology resources;
- Prepare regional programs;
- Recommend local level technology to national level;
- Determine the type of technology and technology package; and
- Feed back information to the research agencies.

### **Private sectors/livestock farmers**

- Act as source of technology;
- Use of technologies; and are
- Partners in mutual relationships.

The Directorate General of Livestock Services carries out final stage multi-location evaluation and experimentation of new technologies identified by the research agencies. This final evaluation is particularly important for high risk technologies before their recommendation in technological packages. Finally, the extension workers act as consultants, utilising their experience and ability to interpret information signals. In the future, strengthening of the systems for the transfer of applied technologies will be emphasized.

## **Conclusions**

Livestock extension in Indonesia has been implemented intensively and effectively since 1979 utilising the Research and Extension Linkage Model as the basis for the transfer of technology from research

agency to farmers. Livestock extension policy is a part of the agriculture extension policy. Implementation of extension activities is based on existing laws and regulations, in which the mechanisms, guidelines for extension, extension institutions, and farmer institutions have been documented. There are still many shortcomings in the implementation of livestock extension, including the preparation of programs or

appropriate technologies, insufficient regional offices acting as the home-base for the extension workers, insufficient person-power (in terms of number and quality), and the failure of farmer institutions to be established throughout all districts of Indonesia. New technologies are thoroughly evaluated and field-tested before being transferred to farmers.

## **Country Papers**

# Ruminants in Plantation Systems in Indonesia

W.W.Stür\*

## The Need for Higher Ruminant Production

THE demand for animal products in Indonesia has increased rapidly over the last few years, largely owing to the need to improve human nutrition and to the increase in household income. There is evidence that the gap between domestic supply and demand is increasing and, despite importation of meat, this has led to considerable price increases (Levine and Soedjana 1991). Similar price increases have occurred in other countries in Southeast Asia. In the Philippines, the retail price for beef has almost tripled between 1985 and 1992 (Stür et al. 1995). Although increases in actual farmgate prices have been lower, cattle and other ruminant production have become increasingly profitable for farmers, and now compare favourably with food crops. Also, food crop targets have been largely met and the Indonesian Government is giving higher priority to the livestock sector.

Ruminant density has increased steadily over the last 10 years (Table 1). From 1981 to 1990, cattle numbers have increased from 6.5 to 10.5 million head, and similar increases have occurred with small ruminants (AARD 1992). Further increases in ruminant number and productivity are limited by the availability of feed.

## Tree Plantation Crops Provide Opportunities for Integration

Ruminant density is often highest in intensive cropping systems, and the opportunity to further increase ruminant density in these intensive systems is limited, since most of the feed resources (crop byproducts and naturally occurring forages) are already utilised. Livestock planners in Indonesia are looking for other areas to increase ruminant production. One of the few areas where feed resources are not fully utilised, and where there is good potential to further increase the availability of feed is in tree plantations.

There are approximately 7 million hectares of coconut, rubber and oil palm plantations in Indonesia (Fig. 1). Coconut and rubber plantations are almost exclusively in the hands of smallholder farmers, while approximately 50% of the area planted with oil palms belongs to private or government estates. Smallholders are more likely to be interested in diversification and multiuse of the plantation areas than are estates, since they need to make full use of their limited land resources. Many smallholders intercrop tree plantations, provided there is sufficient light, and keep ruminants which graze naturally occurring vegetation under the trees, or forages which are cut and fed to penned animals. The concept of livestock production under plantation crops is widely accepted by smallholder farmers in Indonesia, and therefore the prospect of increasing animal production in these systems is good.

The integration of animal production with plantation crops has the potential to stabilise or increase income from dual land use. In the case of coconuts, the long-term structural decline in the price of copra as well as unpredictable short-term fluctuations of the local price, have made diversification a necessity (Stür et al. 1995). Income from cattle grazing under coconuts can stabilise and form a considerable part of farm income. A working group in Indonesia estimated that the contribution of the cattle component to total farm income in a coconut-cattle enterprise may be as high as 75% (Iniguez and Sanchez 1991).

## Factors Affecting Animal Production in Plantation Crops

There are a number of factors which affect animal production potential in plantation crops. The overriding factor is the amount and quality of forage available, although animal health may also affect productivity. The most important determinant of forage productivity is the amount of light transmitted through the leaf canopy of the trees.

In rubber plantations, light transmission falls to a level which restricts forage productivity severely within five years (Fig. 2). Obviously, this limits the opportunities for livestock development in rubber (and oil palm

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plantations which have a similar light profile). Tajuddin et al. (1991) suggested altering the planting pattern of rubber to a hedgerow layout which would allow greater light penetration in mature rubber plantations, thus prolonging the period of high forage and animal production. The potential for livestock production is greater in coconut plantations where light transmission increases once trees reach maturity and this allows long-term use of the area under coconuts (Fig. 2).

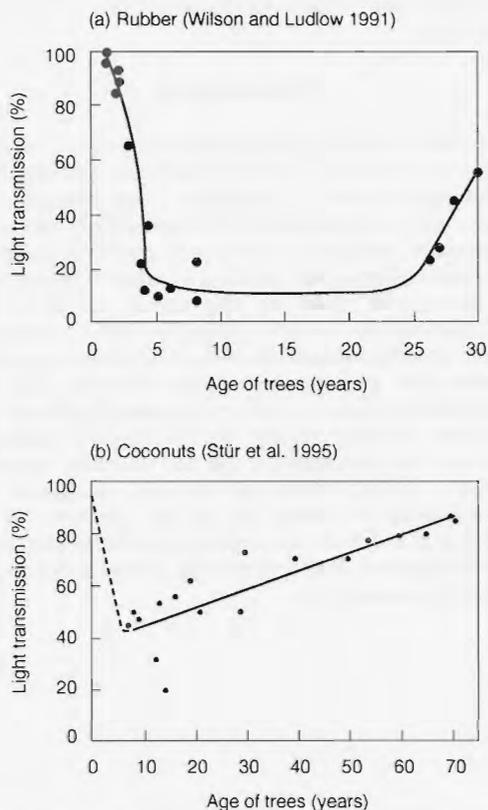
**Table 1.** Ruminant number in Indonesia (AARD 1992).

	1981 (million head)	1990 (million head)
Beef cattle	6516	10520
Dairy cows	113	306
Buffalo	2488	3282
Goats	7790	11230
Sheep	4177	5028

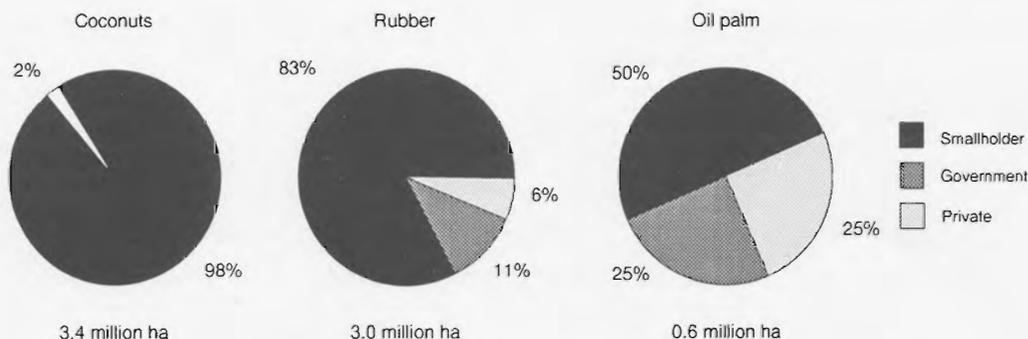
Animal production is often low under coconuts. This is partly related to the low productivity of the naturally occurring vegetation but more importantly to the entry of weeds. Animals tend to concentrate their foraging on the more palatable species, leaving the unpalatable species (weeds) to grow unchecked. Availability of palatable forages quickly declines and this results in low animal production. This limitation can be overcome by planting adapted forage species which are sufficiently competitive to suppress weed growth. Such forages need to be strong and resilient to be able to withstand the heavy grazing and low management inputs likely to occur in smallholder farming systems. Improved forages, possessing these characteristics, were identified during the first phase of the ACIAR-funded project. Further evaluation under field conditions was carried out during the second phase of the project and the results are presented in this proceedings.

The potential for the integration of livestock with coconuts is greater in remote areas, since the area

under coconuts is often fully utilised for food crop production near major population centres. Restrictions to livestock development in remote areas include the provision of healthcare and, importantly, marketing opportunities. Once these requirements are met, the potential for livestock development under coconuts is great.



**Figure 2.** Light transmission through the canopy of rubber and coconuts (tall variety) with age of trees.



**Figure 1.** Area and ownership of tree plantation crops in Indonesia (AARD, 1992).

There are few restrictions in regard to the type of ruminants which can be raised under plantations. Apart from reports that goats grazing rubber plantations can damage the bark of the tree, and that goats and cattle may interfere with latex collection in mature rubber plantations, ruminants and tree plantations are inherently compatible. Grazing animals reduce the need for weeding, increase nutrient cycling and increase income from sale of animal products.

## Conclusions

Ruminants already play an important role in small-holder plantations systems in Indonesia, utilising the naturally occurring vegetation. Opportunities to increase ruminant numbers and productivity are considerable, particularly in the more extensive coconut producing areas. The planting of adapted forages is necessary to ensure the long-term sustainability of forage and thus livestock production under tree plantations. Opportunities also exist to further develop the integration of sheep with rubber, however, this is dependent largely on the development of alternative rubber planting systems which allow a sustained higher light transmission. The use of natural vegetation in mature rubber and oil palm plantations is encouraged to make use of the available feed resource and to minimise the need for herbicides, but stocking rates and consequently animal production per unit area are low.

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# Ruminants in Plantation Systems in Malaysia

Tajuddin Ismail and Chong Dai Thai\*

BEFORE the implementation of double-cropping of paddy in the mid-60s, ruminant production in Malaysia was confined to paddy growing areas. With the advent of double-cropping, ruminants (except for buffaloes) were forced to move to plantations where land area and ready forage was available. With the introduction of ruminants into plantations, the naturalised grasses and weeds previously considered as a liability, were put to good use as feed for the animals. Research had shown that ruminants, mainly cattle and sheep could be favourably integrated into rubber and oil palm plantations. The positive effects of animal integration under plantation crops have been well documented (e.g. Shelton and Stür 1991).

Systematic research on ruminant integration in plantations was started in mid-70s by MARDI, the Rubber Research Institute of Malaysia (RRIM) and the Department of Veterinary Services Malaysia (DVS). Subsequently, in the mid-80s UM, UPM, Guthries and Sime Darby also conducted research, with an emphasis on sheep integration under rubber. Many verification trials were set up in smallholdings, government-backed land schemes, and private estates to assess the commercial viability of rearing sheep and cattle under rubber and oil palm. The initial aim of having ruminants in plantations was to reduce the use of herbicides and cost of weeding through grazing.

This paper discusses the present status of ruminant production in plantation systems in Malaysia and presents some issues considered significant to the future of this sector of the livestock industry.

## Ruminant Population, Production and Consumption

The ruminant population in Malaysia has been low since the early days (Table 1). The annual population growth (%) from 1970–1993 was low for cattle, negative for goats but high for sheep. The production, consumption and self-sufficiency levels of beef and mutton are presented in Table 2. The annual growth in beef production was very small, while annual

growth of consumption was high, resulting in reduced levels of self-sufficiency. In the case of mutton, the annual growth in production was negative while consumption was high, again resulting in low levels of self-sufficiency. As a result of the low ruminant production compared to consumption, Malaysia currently imports about 80% of beef and 93% of mutton requirements valued at US\$60million per year.

## Potential for Integration

Currently there are 1.8 million hectares of land under rubber and 2.1 million hectares under oil palm. At least 25% of the area under rubber (450000 ha), is suitable for sheep rearing and has the potential for carrying 1.35 million sheep (at 3 sheep/ha). At least 40% of the total area under oil palms (840000 ha) is suitable for cattle integration, and can potentially stock 840000 head of cattle (at 1 head/ha). There is great potential for ruminant production to be increased in plantations, and if this can be achieved, it is possible that Malaysia will reduce its importation of beef and mutton and at the same time derive benefits from the integration practice.

Only a small proportion of the plantation area is currently being used for ruminant production. The DVS estimated that in 1993 there were 100000 sheep and 170000 cattle being reared in plantations.

## Reasons for Poor Adoption

Although ruminant integration in plantations has been shown to be technically feasible and economically viable, the adoption rate of this technology is very poor. From adhoc studies and observations made, several unresolved major issues and constraints were identified as the cause of the poor technology adoption, these were:

1. Low-productivity of natural forages under plantations leading to a low-stocking rate and animal production.
2. Poor grazing management, leading to ineffective weed control and an increase in unpalatable species.
3. Lack of suitable sheep breeds for foundation stock.
4. Lack of experience and skill in managing animals.

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## Possible Solutions

Low forage and animal productivity under the conventional planting system are considered to be the most critical limiting factors in the further development of ruminant integration in plantations. Currently, this constraint is being addressed through research efforts conducted by MARDI, RRIM, UPM, and UM. The RRIM is making some headway in solving the problem through adoption of a double hedgerow planting system, and planting improved forages in the wide interrows between the hedges. However, replacing the conventional legume covers with a double hedgerow system, will require major changes in planting policies. RRIM, the Ministry of Agriculture and DVS have initiated a program to highlight the benefits of the double hedgerow planting system to policy makers and heads of relevant organisations in Malaysia.

**Table 1.** Ruminant population in Malaysia (number).

Year	Cattle	Goat	Sheep
1970	301220	332520	38180
1980	481424	312069	59283
1990	614498	281759	199909
1991	637663	288516	234901
1992	662914	292901	296834
1993 <sup>a</sup>	640306	292354	372579
% Annual growth	5.6	(0.5)	38.1

<sup>a</sup> Estimate

( ) = Negative growth

Source: Department of Veterinary Services, Malaysia (1994).

Poor grazing management is a problem related to poor understanding of natural forages. With more information gathered through continued research, appropriate techniques of grazing management will be formulated to achieve good animal performance as well as effective weed control. Production strategies should be tested in situ in cooperation with key implementors to achieve direct transfer of expertise and experience.

The most suitable breeds of cattle and sheep for rearing in plantations are yet to be determined. The local Kedah-Kelantan cattle and Malin sheep have poor growth performance and their numbers are limited. Exotic, temperate breeds do not survive well under Malaysian climatic conditions and their reproductive performance is very poor. Contractors have great difficulty in obtaining good stock. Improved crossbreeds of cattle and sheep are limited and expensive—their numbers should be increased by well-managed breeding programs. Efforts should continue to identify suitable new breeds for stocking plantations.

Few people in the plantation sector have experience in handling animals in large numbers, and this factor has contributed to the current poor herd/flock performance and failure of projects. All available proven technologies should be packaged and disseminated. A more systematic and comprehensive training program for project supervisory staff and farm hands should be carried out.

## Conclusion

There is great potential for ruminant integration in plantations. Since Malaysia imports 79% of its beef and 93% of mutton requirements, all efforts to increase the adoption of ruminant integration should be made. Constraints of low forage and animal productivity can possibly be solved by adoption of the

**Table 2.** Production, consumption and self-sufficiency levels of beef and mutton in Malaysia.

Year	Beef			Mutton		
	Production (t)	Consumption (t)	Self-sufficiency (%)	Production (t)	Consumption (t)	Self-sufficiency (%)
1970	12980	14935	86.9	1030	4147	28.2
1980	13043	20476	63.7	762	6607	11.5
1990	12244	50879	24.1	658	7283	9.0
1991	12704	56942	23.3	672	7473	9.0
1992	12752	58619	21.8	658	9035	7.3
1993 <sup>a</sup>	13338	63309	21.1	677	9495	7.1
% Annual growth	0.1	14.7	(3.4)	(1.6)	5.9	(3.2)

<sup>a</sup> Estimate

( ) = Negative growth

Source: Department of Veterinary Services, Malaysia (1994).

double hedgerow rubber planting system and the planting of improved forages in the wide interrows. Grazing management research should continue in an effort to identify appropriate systems for sustainable forage production and effective weed control. Suitable breeds for plantations should be identified and made available in sufficient numbers. Systematic and comprehensive training programs should be carried out to improve the knowledge and skill of implementors.

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# Ruminants in the Coconut-based Plantation Systems: Research and Development in the Philippines

A.C. Castillo\*

COCONUT (*Cocos nucifera*) is a principal plantation crop in the Philippines and plays an important role in the economy of the country. Over 3 million ha of agricultural lands are planted to coconut (PCA 1991), with 13% utilised for ruminant production (Moog and Faylon 1991). Approximately 3.5 million farmers and landless workers depend on the coconut industry for their livelihood. While other plantation crops e.g. rubber (*Hevea brasiliensis*) and oil palm (*Elaeis guineensis*) also have potential for livestock integration, their significance in terms of area and contribution to the economy is much less than the coconut.

The coconut industry is characterised by inequality in the distribution of resources and income. Over 90% of coconut areas are smallholdings of < 5.0 ha. The farmers income is about 2.0% of that earned by large landholders and less than 2.0% of the income of traders and processors (PCA 1988). This great disparity in incomes, if not checked, may bring about the collapse of the industry. Therefore, improving the income level of smallholders through product diversification, is a major concern of both researchers and policy makers working in the industry.

The integration of ruminants into coconut plantations offers a potential increase and diversification of income (Moog and Faylon 1991; Shelton and Stür 1991). Small farmers would have the opportunity to cash in their surplus animals in times of crop failure. Other advantages of such dual use of land include the enhancement of nutrient cycling and a reduction in weed invasion.

This paper presents progress made in research and development of ruminant production under coconut palms in the Philippines in relation to the national development goal of self-sufficiency in red meat as well as milk and milk products.

## Ruminant Industries

### Livestock population

Cattle, buffalo and goat are the major ruminant animals raised in the country. The production of these animals is closely allied with farmers' activities and lifestyle. Approximately 95% of the ruminant population are raised on small farms for draught purposes and as a source of cash in times of need.

From 1986–1991, an average yearly decline of 1.4%, 2.3% and 0.5% was experienced for cattle, buffalo and goat numbers respectively (Fig. 1). Poultry and swine numbers have shown steady growth over the same period, demand for beef products increased at a rate of 4.2% per year (Gorrez 1994). Thus, the resulting gap between supply and demand had to be narrowed by liberalising the importation of both live cattle and frozen beef products. For cattle for fattening, the allowable annual quota was set at 54000 head/year.

Figure 2 shows the increasing trend in the importation of beef cattle and beef products. From 1100 head in 1986, feeder cattle import peaked at 24315 head in 1991, valued at US\$10.81 million. A similar trend was observed in beef products, which grew from 2518 t in 1986 to 11000 t in 1991. However, despite the deregulation policy on imports, domestic retail prices of beef products, at US\$6–8 per kg depending on cuts, remain higher than the world market price.

### Prevailing production practices

As with other Southeast Asian countries, ruminant raising in the Philippines is predominantly a backyard enterprise. Livestock are raised for agricultural as well as for social reasons and often not for business. Selling of animals is done only when the need arises. The cultivation of improved forages is not normal practice, and farmers rely heavily on crop residues and weeds from croplands for feed supply. Animals are either stall-fed or tethered during the crop growing season. Under coconut plantations however, animals are tethered or grazed all year round. In the

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majority of the villages, livestock are usually maintained on a low to medium plane of nutrition.

With the gradual decline of the industry over the last decade, coupled with the import liberalisation policy of the government, a commercial approach to ruminant production by farmers is required to meet the challenges being faced by the industry.

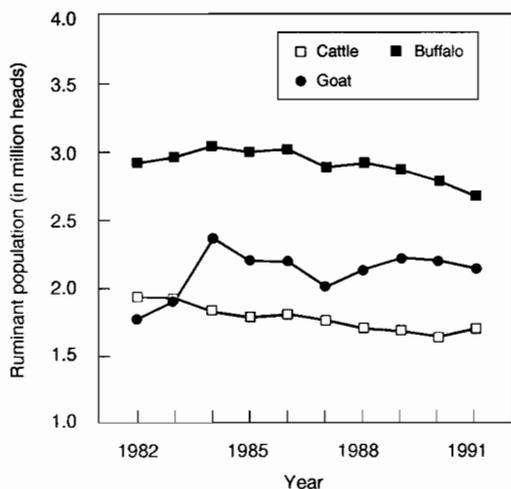


Figure 1. Yearly changes in ruminant population, Philippines.

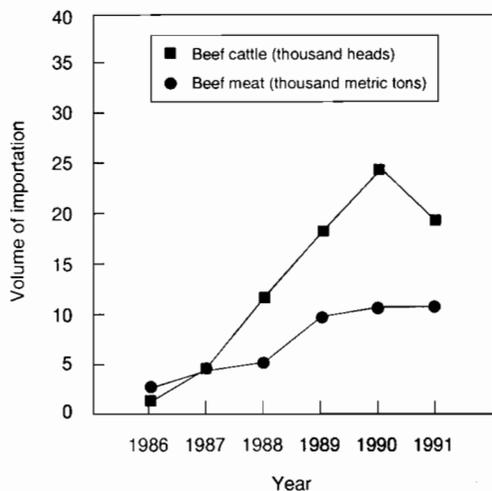


Figure 2. Yearly changes in the importation of beef cattle and frozen beef products, Philippines.

### Government policy

The government has manifested its strong support for the development of a viable livestock industry. The Philippine Medium Term (1994–1998) Live-

stock Development Program has a total budget of US\$2.2 billion, of which 72% is allocated for cattle development (Gorrez 1994). Built-in to this program, is the identification of 44 Key Livestock Development Areas (KLDA) throughout the country where crop–livestock integration practices are now being popularised. Moreover, active participation of smallholders through the cooperatives movement is being encouraged through provision of liberal credit, marketing facilities and other support services. More explicitly, the present administration has opted for a more direct but sustained intervention in the industry to arrest the declining trend in livestock population by the year 2000.

## Ruminant Integration

### Native pasture species under coconut plantations

Coconut is a relatively open-canopied perennial allowing the growth of understory vegetation. Trung et al. (1991) studied the native vegetation under mature coconut palms in five villages of Sta. Cruz, Laguna (climate: distinct wet and dry; monthly dry season temperature: 26°C; monthly wet season temperature: 27°C). Annual dry matter yields varied with sites and ranged from 2.2 to 5.1 t/ha. A total of 83 species were identified comprising of 11 legumes, 11 broadleaf, 51 shrub species and 10 grasses. Species predominant were:

- Grasses: *Axonopus compressus*, *Paspalum conjugatum* and *Cryptococcum patens*
- Legumes: *Pueraria phaseoloides*, *Mimosa pudica* and *Pueraria lobata*
- Broadleaf: *Ageratum conyzoides* and *Blechnum pyramidatum* and,
- Shrub: *Triumfeta bartramia*

Cutting frequency and season over the 2-year period had no significant effect on pasture botanical composition (Table 1). By contrast, treatment effects on forage quality in terms of CP content and IVDMD were significant.

In contrast to the cutting experiment of Trung et al. (1991), Faylon et al. (1991) reported significant changes in pasture composition after one year of continuous grazing by sheep (Table 2). In the dry months, the legumes, (particularly *P. phaseoloides*) became robust while the grasses were stalky. These conditions affected the feeding preference of animals, and ultimately the pasture composition.

The increase of unpalatable weeds, particularly *Elephantopus* spp., within a year of grazing was reported by Valenzuela et al. (1992) and Moog et al. (1992) at the stocking rate of 1.0 animal unit (AU)/ha. These studies were conducted in two separate areas of the Bicol region where *P. conjugatum* and *I. cylindrica* are the predominant grasses under coco-

nuts. A 3-fold increase in weed component was obtained by Valenzuela et al. in the *P. conjugatum*-dominated areas after 2 years of cattle grazing. A similar trend was reported by Moog et al. (1992) in *Imperata*-dominated paddocks after being grazed by buffalo for two consecutive years. A much lower stocking rate is therefore needed to maintain the dominance of native grasses in areas under coconuts. The nutritive value of native vegetation under coconut is relatively low with IVDMDs of 47–50%, although CP was moderate at 11–13%.

**Table 1.** Botanical composition (% total DM yield) of native pastures under coconut at two cutting frequencies during dry and wet seasons.

Vegetation type	Cutting frequency		Season		Mean
	45 days	60 days	Dry	Wet	
Grasses	42	52	46	49	47a
Legumes	17	12	14	15	14b
Broadleaves	39	34	37	36	37c
Shrubs	2	2	3	1	2d
SEM = 6.2					

Main effect means without a common letter are statistically different ( $P < 0.05$ ).

Source: Trung et al. (1991).

**Table 2.** Botanical composition (% total DM yield) of native pasture under coconut palms subjected to two grazing systems, March 1989–February 1990.

Grazing system/ period	Botanical composition (%)		
	Grasses	Legumes	Forbs
<b>CGS<sup>a</sup></b>			
Start of the trial	48	48	4
End of the trial	64	14	22
<b>FGS<sup>b</sup></b>			
Start of the trial	79	3	18
End of the trial	62	24	14

<sup>a</sup> Continuous grazing system

<sup>b</sup> Flexible grazing system

Source: Faylon et al. (1991)

### Animal performance

The integration of ruminants under coconut plantations is a common practice in some areas of the country, particularly in the Mindanao region (8°N, 125°E). Few formal studies evaluating the performance of the grazing animals under plantation crops in

the Philippines are available. Valenzuela et al. (1992) compared the liveweight performance of cattle grazing N-fertilised versus unfertilised *P. conjugatum*-dominated pastures stocked at 1.0 AU/ha. A positive effect of fertilisation on liveweight gain was obtained only in the 1st year. In this period, the average daily gain (ADG) of animals grazing the fertilised paddock (range: 0.72–0.79 kg) was 2-times higher than the control (range: 0.32–0.34 kg). Liveweight gains (LWG) did not vary significantly in the second year.

Moog et al. (1992) evaluated the potential of the common centro (*C. pubescens*) for improving the productivity of *Imperata*-dominated areas under coconut. Test animals were young female buffaloes which were allowed to graze in their respective paddocks all-year round. Except for salt, no supplements were provided.

ADG of buffaloes grazing native/centro at 1.0 AU was the highest (Table 3). This may be attributed to the higher quality and quantity of available feed. Liveweight performance of animals at 2.0 AU/ha was limited by forage availability and a significant increase of unpalatable weeds in the pasture. Legume introduction and the subsequent grazing of animals had no adverse effects on nut production despite the changes in pasture composition with time.

The high seasonality of production is a major limitation of native vegetation under coconuts. F.A. Moog (unpublished data) found undercanopy native vegetation capable of supporting 10 mature sheep/ha gaining 65 g/head/day in the wet season. However, employing the same stocking rate in the dry season resulted in an ADG of only 8 g (F.A. Moog, unpublished data). Thus, some attempts were made to improve production through the introduction of improved grass species.

Experiences and early research findings, (e.g. Subere and Gerona 1986) have indicated that upright-growing grasses, particularly common guinea (*Panicum maximum*) and napier (*Pennisetum purpureum*), would grow well under coconuts. Attempts to promote these grasses among farmers failed, as these species interfered with nut harvesting operations. The direction of recent research has therefore shifted to investigation of low-growing stoloniferous species, particularly signal (*Brachiaria decumbens*) and humidicola (*B. humidicola*).

In volcanic soils, signal grass pastures under coconuts may be stocked at 2.0 AU/ha with cattle gaining 0.30 kg/day with no adverse effects on nut production (Moog et al. 1993). This is comparable to the ADG of 0.32 kg obtained by A.F. Marbella (unpublished data) in signal/cook-stylo (*Stylosanthes* cv. Cook) mixed pasture stocked at 2.5 AU/ha under rangelands conditions. Moog et al. (1993) found no advantage in liveweight gain by lowering stocking rate to 1.0 AU/ha, despite an increase in pasture on offer. Clearly,

**Table 3.** Mean liveweight performance of buffaloes at different pasture treatments (August 1986 to September 1988)

Parameter	Treatment		
	Native pasture	Native/centro	
	1.0 AU/ha	1.0 AU/ha	2.0 AU/ha
Average daily gain (kg)	0.14c	0.25a	0.20ab
Total LWG/head (kg)	106b	185a	151ab
Total LWG/ha (kg)	106c	185b	302a

Means within row without a common letter are statistically different ( $P < 0.05$ ).

Source: Moog et al. 1992.

there is a need to find good quality legumes that can be successfully incorporated into signal grass pastures for further improvement of animal performance. The potential of *Arachis pintoi* under shaded environments for grazing ruminants is still under investigation.

## Conclusions

There has been a continuous decline in ruminant population in the Philippines over the past decade. However, vast tracts of land under coconut plantations remained untapped for livestock production.

There is a considerable range of naturalised species growing underneath the coconut plantations, but animal production on these areas is often limited by the low dry matter yield and seasonal availability of natural vegetation. A higher level of ruminant production can be achieved with sown grasses and legumes.

In view of the limited range of improved pasture species that have been evaluated under plantation crops in the country, there is a need to conduct more site-specific studies involving a much wider range of promising species. Finding high quality and persistent legumes that can combine well with signal and humidicola grasses is a priority area for future research.

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# Forages Research in Southern Thailand

Pravit Sophanodora\*

PLANTATION crops such as rubber, oil palm and fruit trees utilise large areas of agricultural land in southern Thailand. The Thai Government has encouraged diversification of agricultural production in the region in order to broaden the agricultural commodity base and to increase opportunities for farmers. Animal production is one of the opportunities offered to farmers. Although pure-bred and cross-bred cattle are being introduced to farmers, forage production receives little attention. Presently forage production is far below animal requirements both in terms of quantity and quality.

## Land

Southern Thailand is situated 6°–11°N and comprises 14 provinces with a total area of 7 million ha. About 39% of the total area is utilised for agricultural production which is classified into 6 major uses; paddy field, permanent tree crops (rubber, oil palm and fruit trees), annual field crops, vegetables, flowers and idle land (Table 1). With the exception of Pattalung Province, the area of permanent tree crops is a major land use in all provinces (Fig. 1).

## Soil

The topography of southern Thailand is made up of distinct ranges of hills and mountains. The two principal ranges are the Phuket range in the west and the Nakorn Si Thammarat range in the east. The landscape between the main ranges comprises low hills and undulating terraces. The west coast is indented with many estuaries, narrow plains and terraces. In contrast, the east coast is smooth with wide coastal terraces and plains. Soils in southern Thailand can be classified into coastal, upland, steep-land, and recent-alluvial soils.

Most soils in the region are infertile with major deficiencies in P, N, K, S, Cu (Nilnond et al. 1986). In addition, problem soils (acid, peat, sandy and alka-

line soils) are widespread along the coastal area, particularly in the lower South which covers approximately 65% of the total area. (Panichapong 1982). Among these problem soils, peat and acid sulfate soils (>80000 ha) are the most difficult and costly to utilise.

## Climate

Rainfall is influenced by two monsoons (Fig. 2). First, the northeast monsoon (mid Oct–mid Feb), and second the southwest monsoon (May–Sept).

The total amount of annual rainfall ranges from 1710–2619 mm on the east coast, and from 2327–4278 mm on the west coast. The average number of rainy days ranges from 164 on the east coast, to 184 days on the west coast. Evenson (1983) analysed the climate of the Songkhla basin and found that moisture stress (precipitation:evaporation ratio < 0.3) may occur in some areas. This may limit crop and pasture production (Pauvert and Dhesprasith 1988).

The temperature in southern Thailand ranges from a minimum of 16°C to a maximum of 37°C with a mean temperature of 27°C. Daylength varies from 12.5 hours in January to 13.4 hours in July. Solar radiation ranges from 17.8 to 23.1 MJ/m<sup>2</sup>/day at Hat Yai.

Table 1. Land utilisation in southern Thailand in 1991.

Classification	area (ha)	%
Total area	7071514	(100)
Agriculture area	2773426	(39)
Paddy field	577986	21
Tree crops	1939349	70
Field crops	24055	0.4
Vegetables	10255	0.4
Flowers	116678	4
Pasture and idle land	26879	1
Forest	1344894	(19)
Unclassified	2953198	(41)

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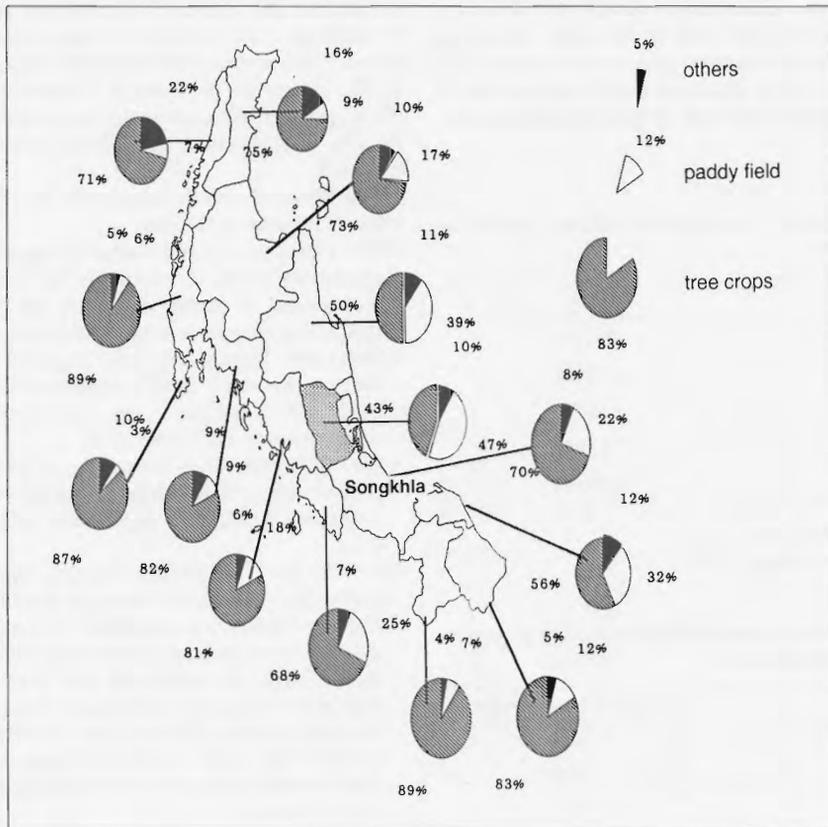


Figure 1. Major land use in 14 provinces of southern Thailand.

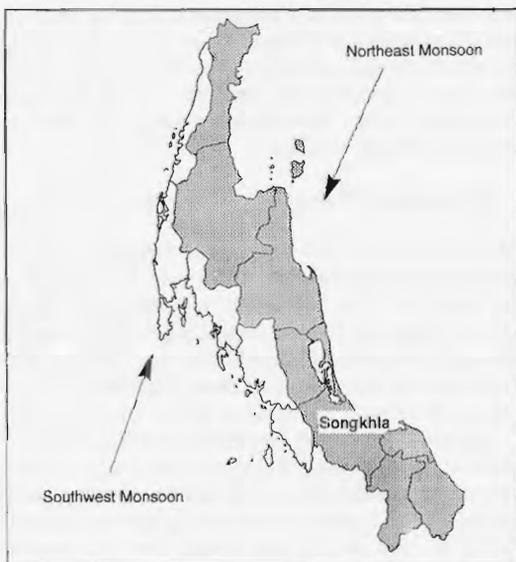


Figure 2. Monsoonal direction and rainfall in southern Thailand. East coast ; West coast

## Animal Husbandry and Pasture Production

Tree crops are widespread in southern Thailand, and ruminants (Table 2) are often raised in conjunction with plantations and paddy rice fields. Livestock production is closely linked to cropping, and animals are fed on native grasses or crop residues. It is difficult to estimate the area used for forage production or grazing, but the agricultural area per animal unit (AU) may be used to roughly estimate the supply of roughages. This figure varies greatly among provinces (Table 3).

Commonly, livestock are grazed on communal land, upland areas, and lowland areas after rice. The dominant native species are *Digitaria* spp., *Chrysopogon* spp., *Eragrostis* spp., *Axonopus compressus* and *Panicum repens*. The use of cover crops and natural vegetations under plantations as animal feed is limited. The Department of Livestock Development (DLD) recommended several species for pasture production, including *Brachiaria ruziziensis*, *B. mutica*, *Panicum maximum* cv. Common and cv. TD58, *Paspalum plicatulum*, *Stylosanthes hamata*

cv. Verano and *Centrosema pubescens*. However, these species are used only in the areas where the DLD or other government agencies are active. The limited use of these species is mainly due to lack of good seed supply and lack of good extension services.

**Table 2.** Number of ruminants in southern Thailand in 1992.

Animal type	Head
Cattle	966812
Buffaloes	154899
Goats	55974
Sheep	17954
Animal units	1140193

1 head of cattle or buffalo = 1 AU

4 heads of goat or sheep = 1 AU

**Table 3.** Provincial ruminant density (ha/AU) in southern Thailand in 1992.

Province	ha of agricultural area/AU
Chumporn	5.09
Ranong	5.45
Surat Thani	5.74
Pang Nga	8.87
Phuket	8.97
Krabi	6.62
Nakorn Si Thammarat	1.92
Trang	3.48
Patthalung	1.23
Satun	2.00
Songkhla	2.00
Pattani	0.98
Yala	3.51
Narathiwat	2.36

## Pasture Research and Development

Two main government agencies are involved in pasture research and development in southern Thailand. These are DLD, and the Faculty of Natural Resources (FNR). The focus of DLD is mainly extension for livestock development, with less emphasis on pasture research and development. Provincial livestock officers are responsible for animal production extension,

vaccination and artificial insemination programmes. In addition, five research stations responsible for research and development on animal feed, are located in five provinces in southern Thailand. During the 1970s, pasture under coconuts was actively promoted by The Thai Institute of Science and Technology Research.

The research works conducted by FNR during 1982–1994 were as follows:

- 1982. Humphreys (1982) suggested special attention should be given to continuity of forage supply, introduction of pasture legumes, soil fertility, and integration of pasture with other crops.
- 1984–1988. Santipracha and Supapol (1986) and Santipracha et al. (1987) conducted research and published articles on *Desmodium* and *Aeschynomene* seed production.
- 1988–1993. The Thai–Australian project conducted pasture research to identify suitable species and management for goat production in low fertility soils.
- In 1988. The Thai–French Farming System Project produced a preliminary report on dairy farming systems in Phatthalung province. This led to a more detailed experiment on pasture and milk production in the area. An additional aim was to develop appropriate diagnosis techniques for assessing dairy farming systems. Ferwoot and Koffeman (1993) reported that urea molasses block supplements could benefit dairy cows in Pathallung and Narathiwat provinces.

The research stations of FNR, located at Klong Hoy Khong and Ta Chiat, together with the facilities of DLD at Satun, Trang, Nakorn Si Thammarat, Narathiwat and Chumporn are experimental sites for research and development on forages and pasture in the region. However, the lack of well trained researchers, equipment and support funds are reasons for the slow progress of forage and pasture research and development in southern Thailand.

## On-going Forage Research at FNR

Major constraints to forage production identified by FNR research include sandy soil with low fertility, a dry spell of 1–3.3 months, water-logging, shade (under plantations), and seasonal production patterns. Animal production is integrated in rice cropping systems utilising native species along roadsides (11 species are dominant) and standing rice straw and weeds.

Improved species are becoming more important but there is a need to study the adaptation of new species. Adaptation studies have been conducted using three main criteria: (i) good growth during rainy season, (ii) ability to reproduce through seed, and (iii) survival during dry spell. Preliminary results are summarised

in Table 4. Fodder crops have potential for cut-and-carry systems. Pearl millet (*Pennisetum americanum*), sweet sorghum (*Sorghum bicolor*) or hybrid sorghum and Napier (*P. purpureum*) are potentially good for silage and green cut during the rainy season or dry season in irrigated areas.

Nutrient constraints include P, N, which are essential for grasses in several soil types; and P, K, Cu, S, Mg, Mo which are essential for legumes. Soil pH should be raised to over 5.5 with lime application. Approximately 200 kg N and P are required for maximum growth of *B. mutica*. About 2 t of rock phosphate/ha is recommended for *S. hamata*.

Work has also been conducted on species suitable for water-logging and acidic soils. Cultivation techniques for better establishment of grasses into cover crop swards have been studied.

Seed production research has focused on seed quality. Although Verano stylo, Hamil guinea, and *Paspalum plicatum* flower prolifically and set seed well, production of good seed quality is difficult due to high rainfall during seed maturity and harvesting. This also affects survival and longevity of established swards.

Grazed pasture studies have been conducted. A mixed sward (para, Hamil guinea, plicatum and Verano stylo) established on alluvial acid soil at Klong Hoi Khong research station has supported good growth of crossbred weaners at a stocking rate of 0.6 ha/head. In a detailed study, Kochpakdee et al. (1994) reported that newly established pasture gave good growth rates of browsing goats when supplemented with concentrate feed. However, an economic analysis showed that concentrate supplements were not economic.

**Table 4.** Adaptation of some forage species for use in southern Thailand.

	Common name	Species	Adaptation niche
Grasses	Guinea	<i>Panicum maximum</i> cv. Common, Riversale	Good soil
	Ruzi	<i>Brachiaria ruziziensis</i>	Upland
	Para	<i>B. mutica</i>	Lowland
		<i>B. milliformis</i>	Upland, sandy soil
	Humidicola	<i>B. humidicola</i>	Lowland, shade
	Napier	<i>Pennisetum purpureum</i>	Good soil
	Paspalum	<i>Paspalum plicatum</i>	Lowland, acid soil
	Legumes	Gamba	<i>Andropogon gayanus</i>
Verano stylo		<i>Stylosanthes hamata</i> cv. Verano	Upland
Seca		<i>S. scabra</i> cv. Seca	Upland
Leucaena		<i>Leucaena leucocephala</i>	Upland pH>5.5
Cassia		<i>Cassia rotundifolia</i>	Dry spell

## Conclusion

The integration of livestock production into farming systems contributes to the development of more sustainable agricultural systems in Thailand. Planted forages and pasture are not widely used by farmers in southern Thailand. Livestock extension and services are available in all provinces of the region. The major constraints limiting adoption of improved forages systems are the physical and socioeconomic environments. Information exchanges between researchers in countries with similar agricultural production environments can be valuable.

## Acknowledgment

I would like to thank ACIAR for inviting me to participate in this meeting.

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# Ruminant Feeding Systems and Forages Research in Vietnam

Le Viet Ly\*

VIETNAM is a tropical country with a monsoonal climate (Table 1). The population of 71 million live in a land area of 332 000 km<sup>2</sup>, of which only 0.2% is arable. Vietnam's agriculture is based on rice production. Other important crops include maize, sweet potato, potato, cassava, groundnut, soyabean, sugarcane and fruits, and the perennial industrial crops rubber, coffee, coconut and tea.

The livestock sector produces 25% of agricultural output, with most production by smallholder enterprises consisting of pigs, cattle, and poultry.

The recent adoption of intensive farming technologies has enabled Vietnam to overcome a long period of grain deficit. In 1989, Vietnam began exporting excess grain abroad and has since become an important rice exporter in the world market.

Due to high population pressure (0.1 ha arable land/capita) priority has been given to the development of agriculture. Sustainable agricultural development is not only an urgent priority to improve the life of millions of farmers but also an integral link in Vietnam's environment protection strategy.

Traditional farming is based on an integrated system, producing rice, root crops, vegetable, fruits, livestock, poultry (especially ducks) and fish in smallholdings. There is much to learn from, and also to contribute to, this system.

**Table 1.** Climatic summary for North and South Vietnam.

	Mean annual temp. (°C)	Average humidity (%)	Mean annual rainfall (mm)
North Vietnam	23.5	84	1680
South Vietnam	27.5	80	1950

\* National Institute of Animal Husbandry, Vietnam.

Vietnam can be divided into the following 7 agricultural zones according to the terrain, ecology and economic conditions: 1. Northern mountainous and middle high land; 2. Red River Delta; 3. Central Coast of Northland; 4. Central Coast of Southland; 5. Central Highland; 6. North East of Southland; 7. Mekong River Delta.

Different crops are cultivated in intensive farming systems, including 4.26 million ha for rice cultivation; 1.28 million ha for subsidiary crops and short-term industrial crops; 860 000 ha for perennial industrial crops; 173 000 ha of water surface areas for fish production; and 332 000 ha for pasture.

Livestock numbers as recorded in the 1992 census were: pigs—12.14 million; cattle—3.151 million; buffalo—2.885 million; goats—0.312 million; sheep—3000; deer—10000 and poultry population—108 million (including a duck flock of 25 million).

Deer farming is well developed in two provinces, Nghe An and Ha Tinh, in the Central Coast of Northland. Annual crops are integrated into tree crop plantations in this region. While goat production spreads throughout the whole country, sheep production is concentrated only in one province, Ninh Thuan, in the Central Coast of Southland.

## Cattle Rearing, Ownership and Farm Size

Ninety-five percent of the cattle herd and 98% of the buffalo herd belong to the private sector. Ownership pattern varies from 2–3 head per family in cropping areas up to 10–25 head per family in upland areas. Bigger herds, with up to one hundred head, exist but are rare.

## Role of Cattle and Buffalo in the Farming System

Farmers are dependent on cattle and buffalo for draught power to plough and prepare paddy rice and other food crop areas. Cattle are used mainly for 'dry'

cultivation and buffalo for 'wet' cultivation areas. Whilst there has been some mechanisation, using 2- or 4- wheel tractors, (particularly in the Mekong Delta) the main form of power is still draught oxen and buffalo. This situation is likely to continue for at least the next 10 years.

A complementary system has evolved, in which draught oxen and buffalo have adapted to living on fibrous rice straw with some additional grazing of native pasture on paddy bunds and other wastelands. Dung, composted with other residues, is used to fertilise rice crops. This manure is the only organic fertilizer which the rice receives.

Given the poor diet and a period of negative weight gain during dry season, cattle and buffalo have shown a great capacity to survive. Their productivity is very low however, with calving percentage of 40–60% for cattle and lower for buffalo. Growth rates and body size are small. Adult local cattle reach only 160–180 kg and 220–240 kg for cows and oxen, respectively.

In the past, meat production from cattle and buffalo was regarded as a secondary product. Cow and draught oxen were finally sold when they were too old to breed or work. This occurred at about 10–12 years of age. Whilst most farmers attempted to finish these cattle by feeding additional concentrate for 30 or more days before sale, the meat was still old meat.

With the economic revival of the late 1980s, there has been an increase in the demand for beef and more cattle are being produced for meat production. There is now a tendency to slaughter cattle at a younger age to produce better quality beef. Fattening technology remains poor however.

## **Ruminant Feeding Systems in Vietnam**

In the Northern mountains and midlands, cattle and buffalo feeding depends on natural pasture and crop by-products, with rice straw being a less important feed source. Environmental conditions promote the development of buffalo raising here.

In the Red River Delta where pasture lands are restricted, rice straw and crop residues are the main feed sources. Better use of these by-products (through processing) is being investigated. In this region, the cattle herd has increased rapidly while the buffalo herd has remained stable.

In the Central coast of Northland and Southland, stock graze native pastures. Rice straw supplements are fed during the dry season as grass supply diminishes.

In the Central highland, cattle and buffalo are grazed on pastures and in forests. Crop residues are also an important feed source.

In the Northeast of the Southland, stock feeds are characterised by the diversity of agroindustrial by-products (such as brewery residue, molasses, oil cake

and others) available as feeds. Forests are also utilised. Urban demand for beef and milk has increased rapidly in this zone.

In the Mekong Delta there is almost no forest or pasture, and ruminant feeding depends mainly on rice straw and other crop residue. With the expansion of mechanisation the buffalo herd is decreasing gradually.

## **Crop–livestock interaction**

Rice straw comprises at least 33% of the feed resource for cattle and buffalo in Vietnam. In areas where rice production is limited, farmers buy rice straw as fodder. However, rice straw does not enter the cash economy and is retained by the farmers as fodder for cattle and buffalo, for use as fuel, or is occasionally burnt and the ash used as fertilizer. After milling, paddy rice normally yields 65–68% of milled rice, 10–12% bran and 20–25% husk. The bran is freely traded in the market or retained by the farmers. It is mainly used for feeding pigs, with supplementary amounts being fed to draught cattle. The husk is used as fuel.

Traditionally, farmers have used cattle and buffalo for draught purposes. Male animals are castrated and raised as special draught oxen with a capacity of 150 draught days/year. Breeding females are also used for draught purposes. At a calving interval of two years, they are capable of providing up to 90 draught days/year. The preparation of paddy land requires approximately 45 draught days/ha/crop. Draught oxen are therefore capable of preparing 3 ha of sown rice crop per year (1.5 ha of double crop), and female draught animals, 2 ha of sown rice crops (1.0 ha of double crop). These figures represent the theoretical capacity, but in practice only 30 days for cows and 60 days for oxen are required due to the limited area to be cultivated and mechanisation in some areas.

Draught animals and pigs provide dung used for the rice paddy areas. Draught oxen produce approximately 2500 kg dung/year. Despite the fact that the cattle graze for 6–7 hours/day on pasture areas, there is quite a high recovery rate of dung — estimated at 50% of the total. Dung is collected from the stalls where the cattle are kept for 16–18 hours/day, and further manure is collected from the pasture. This dung is composted with pig manure, bedding, mixed rice straw, and human and kitchen waste to produce manure.

## **Impact of cattle and buffalo on household budgets**

Cattle and buffalo make a small but significant contribution to overall household income (Table 2). The contribution of cattle/buffalo income to total budget income is only 3–8% in average households, but increases to 16–19% in cattle-owner households. The main products obtained from cattle and buffalo in Vietnam are draught, meat/offal and manure. The contribution of draught, manure and livestock sales to

**Table 2.** Contribution of cattle and buffalo to household economy.

Items	Average household			Cattle-owner household		
	North	Central	South	North	Central	South
Livestock income as % of total income	17	16	9	30	30	32
Cattle/buffalo income as % of total income	7	8	3	16	19	19
Cattle/buffalo income as % livestock income	42	51	39	53	63	59

Source: Ly and Hieu 1991.

the total income generated by local cattle and buffalo (cow and oxen) is shown in Table 3. The main contribution to income is through the benefits of land preparation, with market sales of manure providing smaller but important sources of income.

### Some Results of Forage Research and Production Studies

The main task of forage research in Vietnam is to identify suitable varieties of grasses and legumes for the 7 agricultural zones. Annual species for integration into cropping systems are also required. Because

**Table 3.** Percentage contribution of products to total cash and non-cash income.

	Draught	Manure	Stock
<b>Cattle</b>			
Cow	62	20	18
Oxen	83	8	9
<b>Buffalo</b>			
Cow	68	11	21
Oxen	80	6	14

Source: Ly and Hieu 1993.

**Table 4.** Fresh weight yield of grass and legume species in Vietnam.

Variety	Forage yield (t/ha/year)
<b>Grass</b>	
1. Elephant grass ( <i>Pennisetum purpureum</i> )	100–170
2. Guinea grass ( <i>Panicum maximum</i> cv. Guinea)	80–110
3. Pangola grass ( <i>Digitaria decumbens</i> )	60–90
4. Sorghum grass ( <i>Sorghum vulgare</i> )	40–45 (per two cuts)
5. <i>Paspalum urvillei</i>	40–50
<b>Legume</b>	
1. Leucaena ( <i>Leucaena leucocephala</i> )	30–55
2. Stylo ( <i>Stylosanthes guianensis</i> cv. Cook)	30–45

smallholder farming systems predominate in Vietnam, improved forages technologies must be compatible with the small-scale farming.

### Grasses for the delta and middle land

The fresh weight yields of various grasses in Vietnam are shown in Table 4. Elephant grass (*Pennisetum purpureum*) was identified as a high-yielding grass suited to a number of different zones in the country. With intensive cultivation, this grass was higher-yielding than other grasses, especially in summer and autumn. Guinea grass (*Panicum maximum*) is considered an important grass due to its tolerance to dry conditions. This grass is best suited to well-drained soil and is used mainly for grazing, but is also useful for cut-and-carry. Pangola grass (*Digitaria decumbens*) can be used for cut-and-carry and making hay, and is used on large farms where conserved fodder is required during winter. Paragrass (*Brachiaria mutica*) is well known for its tolerance of water-logging. It is commonly grown on the banks of rivers, where it may be subjected to flooding.

### Legumes for the delta and the middle highlands

Legume fresh weight yields are shown in Table 4. *Stylosanthes* species were productive in a wide range of zones. In the South, the use of Cook stylo is expanding and seed is easy to collect. *Leucaena* is also well

known and the planted area is expanding. It may be utilised as a cut or grazed forage or dehydrated for conservation. In the poultry industry, forage leucaena is a preferred supplement to improve egg quality.

### **Conclusion**

Ruminant production is largely dependant on agricultural by-products rather than pastures. Livestock are integrated into crop production systems. The development of the cattle and buffalo herds is closely linked to the edaphoclimatic and economic conditions of the different zones in the country. In the Central Zone, the cattle herd is predominant, whereas in the mountainous North and midland, the buffalo herd is the main component of the ruminant herd. Goat and sheep production are of lesser importance to Vietnam's livestock production. Cattle and buffalo

provide an important income source for householders. Their role in providing draught power will be important for several more decades. There is a tendency to develop dairy production around the big cities, with beef being produced in Central Vietnam. Research into forage production in Vietnam has been aimed at identifying forage species adapted to the country's agroecological zones. Short-term forage crops compatible with cropping systems are also being investigated.

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# Ruminant Production in Lao Farming Systems

S. Phatlamchanh\*

LAOS is a land-locked country with a relatively low population (17.1 persons/km<sup>2</sup>) by Southeast Asian standards (Anon. 1990). The climate is humid tropical, (subtropical in mountainous/plateau regions) with distinct wet and dry seasons and annual rainfall ranging from 1600 to 3500 mm. Intensive agricultural production is limited to the lowlands. Conversely, the steep uplands, covering about two-thirds of the country, are more suited to cattle production from pastures and other activities that limit erosion risks. This paper outlines the major ruminant production systems used in Laos and initiatives being planned to assist development of the livestock sector.

## Ruminants in Lao Farming Systems

Rice-based farming systems dominate agricultural production in Laos. Over 80% of the population is involved in crop production producing 57% of the country's GDP. Farms average 1.7–3.0 ha and support 5–8 persons. About 90% of the 1.1 million buffalo and 0.95 million cattle in Laos occur on mixed farms where an average of 3–8 buffalo and/or cattle are kept. Large ruminants are primarily kept to provide draught power for cultivation and crop residues form their basic feed resource. The low productivity of these ruminants is attributed to inadequate supply and low quality of feed resources throughout the year, poor genetic stock and inadequate health measures. Native grasses and crop residues form the basic dry and wet season ruminant feeds respectively and are commonly in short supply towards the end of each season.

## Livestock Markets in Laos

Village traders purchase cattle and buffalo from smallholders for domestic and export sales. Generally, one to two middlemen may be involved before sale to official slaughter houses or to Thai importers. Domestic slaughter houses kill, quarter and deliver to local markets on the same day. 65% of the annual kill

is consumed in rural communities and therefore does not pass through slaughter houses (Anon. 1990).

Approximately 35 000 head of buffalo and cattle were sold into Thailand in 1989 (Anon. 1990). This export market has potential to expand significantly with the development of more efficient selling systems. Whilst the Thai market is predominantly for low-priced live animals, a small market is developing for high quality beef.

## Existing forage resources and feeding systems

Potential grazing areas in Laos are dominated by forests, woodlands, grasslands and savannas. Bahnsch (1990) identified five forage regions based on sociogeographic data. These included:

- the southern pek grass savannas;
- the southern highlands;
- irrigated lowlands;
- rainfed lowlands and uplands; and
- the northern highlands.

Irrigated lowland areas can produce two crops/year and are therefore too valuable to be used for pasture production.

The lowlands along the Mekong River basin are cultivated for rain-fed rice. Average annual rainfall of 1300–1700 mm falls predominantly from May to early October. Double cropping is practiced only in the limited irrigation areas. Vegetables are produced during the dry season on residual moisture in rain-fed rice areas. Livestock are kept almost exclusively for draught purposes in lowland cropping areas.

Stock generally graze for approximately 8 hours/day in many cropping areas during the dry season. Livestock feeds include rice straw and cut-and-carry weeds, native grasses and tree leaves (Table 1). Ruminants commonly lose between 20–30 kg liveweight through the dry season as forage supply and quality decreases. Rice production during the wet season limits their grazing and ruminants are commonly confined to backyards, although roadsides, forests, communal grazing areas and wastelands are utilised. Stored rice straw forms the basic feed for ruminants during the rice season and it is commonly in short supply close to harvest of the subsequent rice crop (September–October). Weight gains of 55–65 kg can be achieved through the wet season.

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**Table 1.** Seasonal feed composition for ruminants (%).

Region	Dry season				Wet season			
	Grazing	Rice stubble	Forests	Other	Grazing	Rice stubble	Forests	Other
Lowland	50	30	18	2	57	38	3	2
Upland/plateaux	67	7	28	1	72	5	17	6

Natural grasslands and open woodlands in Laos offer great potential for extensive grazing systems and cover. Approximately 4 million ha are suitable for development for grazing (Anon. 1990).

The southern savannas are lightly forested, with trees and shrubs covering the native *Arundinaria ciliaris* or 'pek grass' savannas. The young leaf of pek grass is well accepted by livestock but as it matures it becomes coarse and less palatable. Pek grass forms a dense rhizomatous mat which is resistant to fire and heavy grazing pressure, but may limit its ability to form stable associations with legumes (Anon. 1990). Soils in this region are of low fertility and the carrying capacity of the pastures may be as low as 1 head/8–10 ha.

A large proportion of grasslands in Laos occur in the northern mountainous regions (including the Xiang Khouang plateau) at an elevation of 500–1000 m. Crops in this region, including upland rice, maize and other field crops are produced by slash-and-burn shifting cultivation. Large areas of permanent *Imperata cylindrica* dominant pastures exist, particularly on steep lands. This communal grazing resource is heavily utilised and overgrazing and subsequent erosion are common. Rice straw is less important as a ruminant feed than in lowland areas (Table 1). Pasture development work in this region has concentrated on replacement of native pastures with *Paspalum plicatulum*, largely because seed of this species is readily available. This development work needs to be reassessed however as *P. plicatulum* is not well accepted by stock and has relatively low nutritive value (L. Bahnisch, pers. comm.).

Plateaux cover 0.4 million ha in northern Laos and include the Boloven and Xiengkhouang. Annual rainfall varies from 1300–2700 mm and the length of the dry season varies greatly between plateaux. Ruminant production is culturally important to many of the mountain tribes as well as having value for draught purposes and as capital reserves. The Boloven plateau is edaphoclimatically unique in Laos with high rainfall, a short dry season and fertile soils and therefore is heavily utilised for high-value crops. Other plateaux are more suited to pasture development. Existing pastures are dominated by a number of edible non-leguminous forbs, inedible shrubs, *Imperata* spp. and bracken fern (*Pteridium esculentum*) (Bahnisch 1989). Villagers occasionally burn to stimulate early pasture growth in the rainy season.

Grasslands on the Xiengkhouang plateau are dominated by *Chrysopogon* spp., *Themeda* spp. and *Axonopus* spp. Pastures are productive during the wet season, but quickly dry off during the dry season.

Stocking rates of 0.4, 0.32, 0.2 beasts/ha are common in the lowland, plateau and upland areas respectively. (Bounthong 1993).

### Research and development priorities

Development strategies for improved livestock production aim to improve animal husbandry and forage supplies within the existing farming systems. Bahnisch (1990) identified low-input forage improvement technologies, including the oversowing of native species with persistent legumes (eg. *Chaemochrista rotundifolia* cv. Wynn, *Arachis* spp. and *Stylosanthes* spp.) and the undersowing of upland crops with annual legumes (eg. *Crotalaria juncea*). Low input grass species are also being investigated including *Bothriochloa*, *Dichanthium* and *Digitaria* spp.

The livestock subsector is currently constrained by both the number and skills levels of research and extension staff and staff development is a priority area. Forages research in the mid-term will be adaptive and carried out on-farm, with emphasis on the development of stable grass–legume pastures and the integration of fodder trees into the various existing farming systems for each agroecological zone. Government extension services are to be created at a regional level to establish on-farm demonstrations and distribute forage planting materials and improved ruminant breeds.

Participative research programs involving smallholder farmers are planned to evaluate a range of forage species including fodder tree legumes for lowland, upland and plateaux sites. Soil fertility limitations and erosion control techniques are being investigated in upland areas. Tethered grazing on roadsides, supplemented with cut-and-carry feed is appropriate for smallholder farmers in lowland regions, but extensive grazing systems are the norm in upland and plateaux regions.

Introduction of technologies to better utilise agricultural by-products is also planned. The use of urea-treated rice straw and supplementation with urea-molasses blocks are currently being investigated.

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