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# Forages for Plantation Crops

**Proceedings of a workshop,
Sanur Beach, Bali,
Indonesia 27-29 June, 1990**

*Editors:* **H.M. Shelton and W.W. Stür**

# Contents

# Foreword

The countries and populations of Southeast Asia and the South Pacific are rapidly improving their economies and their demand for meat is increasing. Projections of population increase to the year 2000 indicate that demand for meat will not be met and the gap between total requirement and local production will be even greater than it is currently. There is little incentive for increased commercial ruminant production in many countries and animal products are usually produced as secondary by-products of other more important agricultural activities. Clearly this situation will change as policy makers perceive the negative influence of increasing beef imports on their economies.

The shortage of land in many countries ensures that the obvious potential for integrating ruminants with the extensive areas of plantation crops in the region will be exploited. However, the successful exploitation of this resource requires that suitable forage species and management strategies are available. It is with this objective that the ACIAR Project 8560 on Improvement of Forage Productivity in Plantation Crops was initiated in 1988.

The research work of the ACIAR Project Group that is presented in these Proceedings is the result of a genuinely cooperative effort. We have worked closely on the planning and implementation of the program and have attempted to integrate our respective resources in the most efficient manner. We hope that the value of this approach will be evident to our readers.

This publication of the Proceedings has two objectives. It allows the presentation of the first two-and-a-half years of our work. Just as importantly, it has provided the opportunity for our research group to meet other international scientists and share experiences on the topic of forages for plantation crops.

The ultimate objective of the work is to provide the information needed by extension workers and farmers to increase the productivity of ruminants in plantation crops. The opportunity for increasing ruminant production in this way is considerable indeed.

H.M. Shelton
W.W. Stür

Editors

# Acknowledgments

Careful planning and good organisation were the keys to the success of our Workshop enhanced by the location in beautiful Bali. A number of institutions and individuals assisted greatly with the organisation of the meeting.

We thank the Rector of Udayana University, Professor I.G.P. Aduyana, and the Dean of the Faculty of Animal Husbandry for kindly agreeing to host the Workshop in Bali.

We are especially indebted to the untiring efforts of Professor I.K. Rika and his team who organised the venue for accommodation, registration, meeting room, distribution of papers, coffee breaks and pre- and post-workshop field trips. We also thank Mr I.K. Mendra, Mr Oka Nurjaya and his wife Mrs Sri Agung.

It was a pleasure for the editors to prepare the papers for these Proceedings, and we are grateful for the creative efforts of all authors who contributed so much to the Workshop through their presentations and informal comments.

Finally, we wish to thank the Australian Centre for International Agricultural Research (ACIAR), and the ACIAR Forage Coordinator, Dr G.J. Blair, for their sponsorship of the Workshop.

We believe that this volume represents an important addition to the literature and to our understanding of the problems and prospects for promoting forages in plantation crops.

The Editors

# The ACIAR Forage Program

Graeme Blair*

AN increase in human population in the developing world has resulted in a concomitant increase in small and large ruminants. This has resulted in severe competition between crops and animals and has led to an increasing demand for forage resources, generally on land of lower production capability. In northern Australia the cattle population has increased substantially as a result of new technologies such as new forage species and animal supplementation. This has put increasing pressure on rangelands in that region. In addition, the increase in interest in crop agronomy that occurred in Australia during the 1970s has resulted in a fall-off in the number of scientists involved in pasture and forage research.

Australia has a comparative advantage in pasture and forage research in that the country is generally covered by poor soils and has an unreliable climate. This has led to the need to introduce forage species into Australia to build up its animal industry. Early efforts by Australians in forage development in the developing world were hampered by the idea that pastures are grazed. Clearly, in areas of high population density other management strategies, such as cut-and-carry, are an important part of the production system. The ACIAR Forage Program considers a wide range of forage alternatives.

## Goals

The Forage Program is coordinated via a Liaison Project and serves as an interface between the animal and plant production programs and soil management and plant nutrition. The major focus of the program is the adaptation of forage plants to particular niches within production systems in Southeast Asia, the South Pacific and South Asia. Research and development projects there are supported by a newsletter and information network.

The overall goal of the Program is to produce forages at little or no cost, and this production should compete minimally with food crops. This means that production of forages is usually confined to marginal soils which creates special problems for their growth and persistence. Forage production should be part of a sustainable agricultural system and, in this regard, the

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Forage Program has close linkages with the soils and plant nutrition programs. In the area of acid soil development and management, the Forage Program is undertaking studies of plant adaptation to infertile soil conditions. This is complemented by studies of the chemical constraints to plant productivity being undertaken in the soils program.

## Priorities and Their Rationale

The Forage Program consists of four projects. These are designed to select forages for large and small ruminants and cover the adaptation of shrub legumes to acid soils, forages to shade situations under plantations and to saline/sodic soil conditions. In addition to these programs, a project on adaptation of forages to acid soils in Southern China is being undertaken.

The projects within the Forage Program are:

8560  improvement of forage productivity in plantation crops;

8619  forage/shrub production from saline and/or sodic soils in Pakistan;

8836  production and utilisation of shrub legumes in the tropics; and

8925  forage development on red soils of South Central China.

## Management

The Forage Program is coordinated by Dr Graeme Blair, a half-time coordinator seconded to ACIAR. Dr Blair is based at the University of New England.

## Major Achievements

### In developing countries

The production and utilisation of the shrub legume project has identified tree and shrub species for marginal tropical soils. An important contribution in this area is that the projects have identified species which can replace the tree legume *Leucaena leucocephala* which has been devastated by an insect pest in many parts of the tropics. Current studies are investigating the management and the feeding value of such replacement species.

Project 8619 has taken Australian saltbush (*Atriplex* spp.) to Pakistan and identified promising species for use on saline soils in that region. Such species will have a major impact on the productivity of these areas.

Significant areas of Malaysia and Indonesia are covered by plantation crops such as oil palm, rubber and coconut. In these areas substantial inputs of herbicides are needed to control weeds. Project 8560 has identified forage species that will grow in these shaded environments. This has the potential substantially to increase sheep production under these crops, and consequently could lead to a reduction in spraying costs and an increased diversification of income.

Substantial areas of South Central China have severely eroded acid soils. Project 8925 has characterised the climate of these regions and selected forage species capable of growing under such adverse soil and climatic conditions.

The Forage Program has produced an ACIAR proceedings, 'Forages in Southeast Asia and South Pacific Agriculture', which has become a widely quoted source of forage information in the region. In addition, the Program has brought together the Consultative Group on International Agricultural Research (CGIAR) and Australian research institutions involved in forage germplasm storage, distribution, evaluation and multiplication. This has resulted in a proposal being put to the Australian International Development Assistance Bureau (AIDAB) for future funding in this area of forage R&D. In addition, Dr Blair has been acting as Chairman of the Organising Committee for the ACIAR-SEARCA (Regional Center for Graduate Study and Research in Agriculture) International Workshop on 'Technologies for sustainable agriculture on marginal uplands in Southeast Asia' held in the Philippines in December 1990.

Because of the need to assess forage species over a number of seasons and locations, forage projects are generally of a longer-term nature than other projects in ACIAR. This means that at this stage in the life of the Forage Program there is little direct evidence on the economic impact of the projects.

The Forage Program has had a major impact on institutional capacity-building in Indonesia, Malaysia and Pakistan. The collaborative mode of the ACIAR projects has given researchers in these countries a better appreciation of the important link between forage germplasm selection and animal production systems. The provision of small items of equipment and assistance in the modification of existing techniques has allowed increased output from basic facilities in these countries.

The distribution of ACIAR Forage Newsletter and the compilation of a forage database has led to improved links between forage researchers in Southeast Asia and the South Pacific. This means that researchers in the region have greater access to Australian expertise within their own region.

## In Australia

*Leucaena leucocephala* has been planted in significant areas of Northern Australia as a fodder supplement for cattle. The same inspect pest that attacked this species in Southeast Asia is now present in Australia and the inputs from Project 8836 are allowing an introduction of new tree and shrub germplasm into Australia. The research on salt-tolerant forages (Project 8619) has linked with research funded by the Australian Wool Corporation to select more productive and persistent *Atriplex* species for use in saline areas of Western Australia.

The Forage Program has assisted the institutions involved in the projects in Australia to increase their capacity for forage research primarily by the employment of research fellows. This has provided a valuable learning experience for younger scientists. Projects in universities have benefited from a closer contact with agriculture outside Australia. This has led to a broadening of the subject matter taught in forage courses in these universities.

## Major Constraints

The major constraint to the Forage Program is the small pool of Australian scientists who remain in forage research, and their availability to work in collaborative projects. Many forage scientists in Australia are heavily committed to research funded by industries such as wool and meat. This, together with the reduction in activities in pasture research in Australia in the 1970s mentioned earlier, has led to a manpower shortage of experienced scientists in forage research. The ACIAR projects already under way are contributing in a small way to reversing this trend. The long-term nature of forage selection, evaluation, and introduction into farming systems means that a long-term commitment to forage R&D is required. To date this has been achieved by undertaking replacement projects in areas that show promise. The future funding of these longer-term activities requires careful evaluation.

## Future Strategies

It is hoped that the Forage Program will be able to undertake a moderate expansion in the future to encompass projects on seed production and establishment which are two key areas with a major bearing on the success of any forage introduction and utilisation program.

It is envisaged that the program will link more closely with both the Animal Program and the Soils and Plant Nutrition Programs. This will allow the development of forage systems within farming systems and sustainable frameworks. It is envisaged that this will be achieved through joint projects across program areas.

Evaluation of forages growing in small plots under coconuts in North Sulawesi, Indonesia.



Screening for shade tolerance at the University of Queensland Research Farm at Redland Bay, Australia.



Sheep grazing in an 8-year old rubber plantation at RRIM Experimental Station Sg. Buloh, Malaysia.



Heavily grazed *Stenotaphrum secundatum* pasture.



Lightly grazed *Stenotaphrum secundatum* pasture.



Herded sheep grazing cover crops and natural vegetation in young rubber in Malaysia.

Use of cover crops in a young oil palm plantation.



Example of the new hedgerow rubber planting system.



Investigations into the nitrogen nutrition of *Paspalum notatum* in full sun, under a *Eucalyptus grandis* plantation and under shade cloth.



*Arachis pintoi* spreading beyond the evaluation plot - a new legume for plantations?

# Opportunities for Integration of Ruminants in Plantation Crops of Southeast Asia and the Pacific

## H.M. Shelton[*] and W.W. Stür[*]

### Abstract

The advantages of raising livestock in conjunction with tree plantations include increased and diversified income, better use of scarce land resources, soil stabilisation and the potential for higher plantation crop yield through better weed control, nutrient cycling and nitrogen accretion. This paper provides an overview of the plantation and livestock industries in the Southeast Asian and Pacific regions and explores the opportunities for integration.

THE raising of livestock in conjunction with tropical plantation crops is a well established practice. The advantages of such dual use of land are documented and include: (a) increased diversified income; (b) better use of scarce land resources; (c) soil stabilisation; and (d) potential for higher plantation crop yield through better weed control, nutrient recycling and nitrogen accretion.

The topic has attracted significant research and development activity in many countries. An extensive literature documents the potential for integration of pasture and livestock in plantation agriculture (Shelton et al. 1987). In this workshop, it is not our intention to repeat all these previous findings. Our objective is to present the results of some recent research and to review some past experiences, both successes and failures, with the extension of pasture technology to farmers. We believe that this will lead to a better understanding of forage–plantation systems and of the limitations to greater use of forages in plantation crops, and ultimately to improved adoption of new techniques.

The purpose of this paper is to provide an overview of the plantation and livestock industries in the Southeast Asian and the Pacific regions and to explore the opportunities for better integration of the two industries. This will provide a conceptual setting for the workshop.

## Plantation Industries

The plantation crops to be reviewed are rubber *(Hevea brasiliensis)*, oil palm *(Elaeis guineensis)* and coconut

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*(Cocos nucifera)*. These crops play an important role in the economies of the countries of Southeast Asia and the South Pacific. While other crops have potential for integration with livestock (e.g. cashews and mangoes in Thailand, cloves and vanilla in Indonesia, and forestry in the Pacific), they are of lesser importance.

Regional production data show that, relative to the rest of the world, Southeast Asia is the major source of all three commodities (Table 1). Within Southeast Asia, Malaysia and Indonesia are the major producers of rubber and palm oil while the Philippines and Indonesia are the main producers of copra (Table 2).

**Table 1.** Productivity of plantation crops by region ('000 t) in 1987.

| Region | Rubber (latex) | Coconut (copra) | Oil palm (oil) |
|---|---|---|---|
| Africa | 266 | 207 | 1 526 |
| North and Central America | 13 | 223 | 138 |
| South America | 46 | 28 | 333 |
| Southeast Asia | 3 682 | 5 105 | 6 371 |
| South Asia | 360 | 1 468 | – |
| Northeast Asia | 202 | – | 200 |
| South Pacific | 1 | 409 | 158 |
| World | 4 574 | 7 440 | 8 727 |

Source: FAO (1988) and APCC (1987).

The South Pacific region is by world standards a minor producer of the crops (Table 1). However, relative to its population and economies, coconut production is a very important activity. Only Papua New Guinea produces significant quantities of palm oil (Table 2) and minor quantities of rubber latex.

Trade in copra was the principal feature of the early development of many South Pacific countries and involved both subsistence smallholder and large-scale foreign-managed plantations. While the larger countries such as Papua New Guinea and Fiji have now diversified their economies, countries such as Western Samoa, Tonga, Cook Islands, Kiribati and Vanuatu are still dependent on the sale of copra for export income (Ward and Proctor 1980).

**Table 2.** Productivity of plantation crops ('000 t) in 1987 in Southeast Asia and the South Pacific.

|  | Rubber (latex) | Coconut (copra) | Oil palm (oil) |
|---|---|---|---|
| *Southeast Asia* | 3 682 | 5 105 | 6 371 |
| Burma | 15 | – | – |
| Indonesia | 1 000 | 2 200 | 1 698 |
| Malaysia | 1 580 | 197 | 4 533 |
| Philippines | 150 | 2 386 | 25 |
| Thailand | 860 | 205 | 115 |
| Vietnam | 57 | 109 | – |
| *South Pacific* | – | 409 | 158 |
| Cook Islands | – | 1 | – |
| Fiji | – | 13 | – |
| French Polynesia | – | 14 | – |
| Kiribati | – | 12 | 0 |
| Marshall Is. and Micronesia | – | 25 | – |
| New Caledonia | – | 1 | – |
| Papua New Guinea | 1 | 198 | 139 |
| Western Samoa | – | 34 | – |
| Solomon Islands | – | 47 | 19 |
| Tonga | – | 8 | – |
| Vanuatu | – | 53 | 0 |

Source: FAO (1988) and APCC (1987).

The production systems employed vary among crops and between regions and this may influence acceptance of forage improvement. The dominant mode of production of palm oil in Southeast Asia is from large estates, often over 1000 ha; these may be managed by government or private interests. Only in Malaysia and Thailand are there significant commercial independent smallholdings (Barlow 1985).

The system of production of rubber is different as approximately 82% of rubber plantations in Southeast Asia are managed by smallholders. These holdings are less than 25 ha compared with the average estate holdings in Indonesia and Malaysia of approximately 600 ha (Barlow 1983). However, a significant proportion of the Malaysian smallholdings are managed as large blocks in government-coordinated land development schemes. This has enabled the standards of management to be closer to that achieved by the large estates.

We have no precise figures on the proportions of smallholder and estate-managed coconut plantations. However, smallholder involvement is high.

The future prospects for the three plantation commodities is mixed. There is little doubt that the future international demand for fats and oils will rise substantially, and for this reason continued expansion of the area and production of palm oil is anticipated, particularly in countries such as Thailand (Barlow 1985). However, the actual result will depend on the availability and price of competing oils, especially soybean, and on the share of palm oil in the total supply of all other oils and fats (Barlow 1985).

As with palm oil, the future of rubber and potential for expansion will depend on movements in international demand and prices. Following many years of growth, production and consumption of natural rubber has remained relatively stable during the 1980s (Barlow 1983) although there has been a recent increase in demand (Anon. 1989). Increases in the productivity per unit area following adoption of improved technology and management can be expected, especially in the smallholder sectors of Indonesia and Thailand where farmers are becoming more commercially minded (Barlow 1983).

The history of coconut development in Southeast Asia and the South Pacific is similar to that of rubber and oil palm, in that international trade of the commodity commenced about 1850 (Purseglove 1972). In contrast to rubber and oil palm, there has been little expansion in the area planted to coconuts since World War II. As with the other crops, world demand fluctuates, but lower profitability compared to the other crops has dictated little recent expansion or uptake of improved varieties or management. Consequently, many coconut plantations now comprise ageing stands of lower-yielding palms, and managers are experiencing reduced productivity. There has also been a general thinning of stand density, especially in the Pacific region, where destructive cyclones have occurred. The future of coconuts is therefore less certain than the other two crops.

## Ruminant Industries

### Livestock numbers

Ruminant livestock have been a significant historical component of the agricultural sector in Southeast Asia where they are a source of meat for human consumption and of power for transport and agriculture. Current estimates of numbers show a majority of large ruminants in the region, especially cattle (28 million), with only Indonesia possessing significant numbers of small ruminants (18.2 million) (Table 3).

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**Table 3.** Ruminant density ('000 head) in 1987 in Southeast Asia and the South Pacific.

| Country | Cattle | Buffalo | Sheep | Goats |
|---|---|---|---|---|
| *Southeast Asia* | 28 003 | 18 000 | 5 801 | 16 925 |
| Burma | 9 912 | 2 188 | 300 | 1 136 |
| Indonesia | 6 470 | 2 994 | 5 300 | 12 900 |
| Malaysia | 620 | 245 | 75 | 347 |
| Philippines | 1 695 | 2 857 | 30 | 2 027 |
| Thailand | 4 931 | 6 350 | 73 | 80 |
| Vietnam | 2 775 | 2 666 | 22 | 432 |
| *South Pacific* | 586 | 0 | 7 | 128 |
| Cook Islands | – | – | – | 3 |
| Fiji | 159 | – | – | 59 |
| French Polynesia | 7 | – | 2 | 3 |
| Kiribati | – | – | – | – |
| Marshall Is. and | | | | |
| Micronesia | 12 | – | – | 4 |
| New Caledonia | 122 | – | 3 | 19 |
| Papua New Guinea | 123 | – | 2 | 17 |
| Western Samoa | 27 | – | – | 0 |
| Solomon Isands | 23 | – | – | 0 |
| Tonga | 8 | – | – | 11 |
| Vanuatu | 103 | – | – | 12 |

Source: FAO (1988).

Meat consumption projections for Southeast Asia point to a steadily increasing demand for meat which is likely significantly to outstrip production by the year 2000 when self-sufficiency may decline to 62%. This decline in self-sufficiency is expected despite a projected fourfold increase in the level of regional meat production (Remenyi and McWilliam 1986). Demand is being increased by rising living standards and a shift towards urban living.

In contrast to the Southeast Asian region, traditional subsistence animal production in the Pacific region is based on pigs and chickens. There is no tradition of ruminant animal production.

The first cattle, mainly dairy breeds, were introduced into the South Pacific region by missionaries in the late 19th century. Subsequently, cattle became important for weed control in coconut plantations managed by expatriates. World War II had a devastating effect on cattle numbers, particularly in Papua New Guinea and Solomon Islands, but numbers began to increase rapidly in these countries during the 1960s and 1970s with promotion and funding from local governments and international agencies (Shelton et al. 1986).

Total numbers of ruminants in the Pacific region are small by comparison with Southeast Asia, but nevertheless they are significant in terms of the local economies, especially in Fiji, Papua New Guinea, New Caledonia and Vanuatu (Table 3).

As for Southeast Asia, meat production does not meet local demand which is rising dramatically as incomes increase (Ward and Proctor 1980). An exception is Vanuatu, where a modest export industry is being developed.

The ownership patterns for livestock are quite different to those operating for the plantation crops. In Southeast Asia, ruminants are largely in the hands of smallholders. In the Pacific, the majority are held on larger estates, either government or privately owned.

The production systems of the two regions are also entirely different. In Southeast Asia, the proportion of permanent pasture relative to arable land and total livestock numbers is small (Table 4), necessitating high stocking rates and close integration of animals with cropping systems. Farmers therefore rely heavily on crop residues and communal grazing land for feed supply, but it is not normal practice to grow forages. Farmers in Southeast Asia, who have a long history of management of ruminants, keep animals for agricultural as well as for social reasons, and are often not completely commercial in their outlook. These factors have implications for acceptance of pasture improvement technology as will be discussed later in these Proceedings.

**Table 4.** Comparative agricultural land use ('000 ha) in some Southeast Asian and South Pacific countries in 1987.

| Countries | Arable | Tree crops | Permament pasture | Forest |
|---|---|---|---|---|
| Burma | 9 574 | 486 | 362 | 32 385 |
| Indonesia | 15 800 | 5 420 | 11 800 | 121 494 |
| Malaysia | 1 040 | 3 340 | 27 | 19 580 |
| Philippines | 4 530 | 3 400 | 1 200 | 10 950 |
| Thailand | 17 810 | 2 240 | 750 | 14 415 |
| Vietnam | 5 915 | 555 | 315 | 12 950 |
| Total (ha) | 54 669 | 15 441 | 14 454 | 211 774 |
| (%) | 18 | 5 | 5 | 71 |
| Cook Islands | 1 | 5 | – | – |
| Fiji | 152 | 88 | 60 | 1 185 |
| French Polynesia | 5 | 70 | 20 | 115 |
| Kiribati | 37 | – | – | 2 |
| Marshall Is. and | | | | |
| Micronesia | 25 | 34 | 24 | 40 |
| New Caledonia | 10 | 10 | 277 | 708 |
| Papua New Guinea | 31 | 355 | 86 | 38 250 |
| Western Samoa | 55 | 67 | 1 | 134 |
| Solomon Islands | 40 | 17 | 39 | 2 560 |
| Tonga | 17 | 31 | 4 | 8 |
| Vanuatu | 20 | 125 | 25 | 16 |
| Total (ha) | 393 | 802 | 536 | 43 018 |
| (%) | 1 | 2 | 1 | 96 |

Source FAO (1988).

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The Pacific countries with their small populations are relatively well endowed with land. Cattle are therefore grazed largely on permanent pastures, either naturalised or improved in a 24-hour grazing system. The larger holdings are managed as Western-style grazing ranches or integrated in coconut plantations. Almost all smallholder cattle are grazed under coconuts. The standards of animal husbandry vary greatly among both groups.

## Prospects for Increased Integration of Ruminants in Plantation Crops

The trends towards higher ruminant populations and increased meat consumption will require a greatly increased forage supply. Remenyi and McWilliam (1986) suggested the need for a doubling of forage supply over the 15 years to the year 2000. One obvious source of naturally occurring forage and of land for improvement of forage supply is the area under plantation crops.

The potential benefits of integration of forages under plantation crops are well known and some have already been outlined. However, the suitability of the three crops for integration with ruminant production varies. Rubber and oil palm have shorter life cycles than coconuts and planting configurations of the former are such that the period of high light penetration to understorey vegetation is short. This has implications for the duration of forage supply, a topic that will be discussed during this workshop.

Nevertheless, in Malaysia, the arguments for greater integration of ruminants in rubber and oil palm plantations are persuasive. The country produces only 15% of mutton and 55% of beef supplies, and consumption is expected to increase to 12 500 and 50 000 million t respectively by the year 2000 (Wan Mohamed et al. 1987). The same authors suggest that current feed reserves including forages and by-products from plantation crops are capable of supporting more than 1 million cattle or 6 million sheep; and that the progressive plantation sector is sufficiently skilled to integrate livestock to take advantage of diversified income sources and reduced costs of chemical weed control.

Coconut plantations, especially those utilising traditional tall varieties, are more long-lived and more open in their structure, and therefore long-term ruminant production is sustainable.

Smallholder involvement in coconuts is also common so that opportunities for combining livestock under coconuts are more directly relevant to this sector, especially in the Pacific (Shelton et al. 1986). The need for diversified income is also greater with coconuts because of its lower profitability, especially as plantations age and productivity declines.

Intensive commercial ruminant production under plantation crops will require the sowing of productive high-quality forage species which are able to persist under grazing in shaded environments. While considerable progress has been made in the identification of suitable species, especially for coconuts (Reynolds 1988), we believe there is scope for further selection, among world forage germplasm collections, of improved genetic material suitable for the variety of environments that may be found under plantation crops. To improve our chances of success, we must increase our understanding of the biology of shade adaptation.

Improved forage supply is only one aspect of successful integration of ruminants and plantation crops. We also need to understand the animal production parameters of ruminants grazing in plantations so that new developments will be based on sound economic analysis from realistic estimates of productivity.

As research biologists interested in promoting rural development based on the adoption, by conservative producers, of new forages or perhaps even totally new production systems, we must not forget that many other socioeconomic factors may influence the decisions of farmers. Factors such as marketing infrastructure, land tenure, social attitudes, management expertise and availability of credit and information may have a critical influence.

We look forward to a full and open discussion of all of these issues during the workshop.

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# The Environment and Potential Growth of Herbage under Plantations

## J.R. Wilson* and M.M. Ludlow*

### Abstract

Plantation agriculture is a significant contributor to the economy of many countries in Southeast Asia and the Pacific.

This paper examines the effects of the plantation canopy on the environment of the herbage understorey and its capacity for growth. A logical model which provides a basis for discussing plant adaptive changes to decreasing light levels is described. This model in a simplified form allows calculations to be made of the potential growth of grass or legume under various light levels; several examples are presented. Calculated growth rates of pasture are then compared with animal requirements to help assess, in the first instance, what animal production potentially can be supported. Finally, further research needs to provide inputs for this model are suggested.

## The Environment

### Radiation above the tree canopy

SHORT-WAVE solar (SW) radiation in the wet tropics varies with latitude and season mostly between 11 and 22 $MJ/m^2/day$, the average being about 17.2 (Cooper 1975). Horne (1988) found that mean monthly SW radiation at Ciawi in Indonesia (10°S) varied from as low as 9 $MJ/m^2/day$ in January to 17 $MJ/m^2/day$ in December, in most months falling between 13.5 and 17 $MJ/m^2/day$. Calculations from Chen and Bong (1983) for Serdang in Malaysia (4°N) give maximum values for clear days ranging from 22 $MJ/m^2/day$ in June to 27.1 $MJ/m^2/day$ in October. The latter compares with values as high as 32 $MJ/m^2/day$ in a subtropical environment in Brisbane, Australia (27°22'S). The cloudiness of the skies obviously greatly reduces the radiation incident on the plantation areas, and the mean monthly means of Horne (1988) are more realistic values for any calculations using SW radiation input.

While SW radiation (400–3000 nm, Jones 1985) has been most commonly measured by meteorological stations, it is photosynthetically active radiation (PAR) (400–700 nm) which is most relevant to plant growth. Currently the term photon irradiance (PI) is preferred to photon flux density or PAR, and is expressed in the units $\mu moles/m^2/sec.$ ($\mu E/m^2/sec$). PI can be calculated from SW radiation above the canopy using PI = 0.5 SW (Szeicz 1974), and $MJ/m^2/day$ can be converted to moles or Einsteins using 1M (1E) of natural daylight $\equiv 0.23$ MJ (Charles - Edwards 1982).

### Radiation below the tree canopy

*Quality of light*

As sunlight passes through the tree canopy in plantations its quality is altered because the leaves preferentially absorb the light in the 400–700 nm wave band. Blue and red light are reduced compared with green and far-red (Holmes 1981).

Because light in the 400–700 nm wave band is preferentially absorbed by the tree canopy, the proportion of PI to SW incident on the herbaceous understorey may be substantially lower than for full sunlight. Baldocchi et al. (1984) measured a fall in ratio from 0.5 above an oak-hickory forest to 0.27 at the understorey level. Therefore, if SW sensors are used to determine the light available for growth of the understorey, the value will be greatly overestimated if the usual 0.5 ratio of PI to SW is used. We cannot say with certainty whether the ratio should be discounted to 0.27 for rubber, oil palm and coconuts because we

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are unaware of any measurements of this ratio under these tree canopies. The degree of attenuation of PI would probably vary between tree species, depending on the transmission properties of their leaves. Fortunately nowadays, with the common availability of instruments measuring PI directly, this factor rarely has to be taken into account.

Because of the differential absorption of red and far-red light, the ratio of red to far-red (R/FR) falls (Table 1). Such changes in this ratio can be directly measured with a special sensor (Skye Instruments, UK).

**Table 1.** Red/far-red ratios in full sun and under several plantation types. (Shelton and Wilson, unpublished data)

| Full sun | Rubber | | Old coconut | Mature rainforest |
| | Immature | Mature | | |
|---|---|---|---|---|
| 1.20 | 1.07 | 0.62 | 1.03 | 0.43 |

These spectral changes, perceived by plants through the phytochrome system, may induce marked morphogenetic changes in the plants (Smith 1982). Stem elongation can be promoted (Child et al. 1981) and tillering and branching inhibited (Deregibus et al. 1985; Casal 1988; Thompson and Harper 1988). Work with tree seedlings in a controlled environment (Warrington et al. 1988) indicates the effect on stem elongation can be over and above that due to reduced light alone (Table 2).

It also appears that shade-intolerant species may show a greater stem elongation response to reduced R/FR than shade-tolerant species (Smith 1982). No information appears to be available for the tropical pasture species of interest for plantations.

**Table 2.** Effect of red/far-red ratio on stem length (mm) of three tree species (adapted from Warrington et al. 1988)

| Tree species | High light | | Low light | |
| R/FR | 1.40 | 1.52 | 1.01 | 0.34 |
|---|---|---|---|---|
| Pinus radiata | 274 | 399 | 549 | 901 |
| Agathis australis | 1110 | 777 | 954 | 1232 |
| Dacrydium cupressinum | 496 | 286 | 443 | 466 |

*Quantity of light*

The changes in relative light transmission for rubber, oil palm, coconuts and eucalypts with age of plantation are summarised in Fig. 1. There are few data for young coconut and older eucalypt plantations. All four tree species show a rapid decline in light transmission over the first five years, reaching very

low levels in rubber and oil palm. This rapid decline and the low minimum levels in the latter two species impose a severe restriction on pasture growth and survival, although there is some indication that light transmission increases to more moderate levels in old plantations. In coconuts, measured light transmissions in mature plantations range between 50 and 80%, which provide a reasonable environment for pasture growth. It is likely that eucalypts (used in the South Pacific islands) would be similar to coconuts in that light transmissions in mature plantations would be above 40%. The theoretical curve of Nelliat et al. (1974) for light transmission in coconuts, which is also shown in Fig. 1, has been reproduced in many publications. Comparison with actual measurements show it significantly overestimates the minimum light levels achieved, at least for the commonly used tall varieties of coconuts; possibly, it may reflect the situation in dwarf varieties.

A commonly used procedure for light transmission measurements has been to take a reading on a clear day at a single time (usually near noon) and at a single position (usually in the centre of a row). Such measurements may provide a useful general description for comparative purposes between various plantation situations. However, they are not very useful when actual light input is needed to enable a calculation of the potential for pasture production under the tree canopy. Such readings will usually overestimate the average daily light transmission received by the total pasture understorey over a period of time embracing a range of weather conditions giving both clear and cloudy days. When time of day and spatial variation have been taken into account, measurements by Sanchez (these Proceedings) indicate minimum light transmissions under rubber of about 4%, considerably lower than the minimum of about 10% indicated in Fig. 1. For modelling purposes the temporal and spatial variations under the canopy need to be integrated to give the average total daily PI input to the pasture area.

Light transmission of a canopy varies with the proportion of direct to diffuse light. Diffuse light penetrates better than direct light because it emanates from the whole hemisphere of the sky rather than from the point source of the sun. Therefore measurements taken on a clear day will underestimate transmission of light under the trees; this may be of special importance in the tropics because of the high incidence of cloudy weather resulting in a high proportion of diffuse radiation. The most precise measurements are obtained by integrating PI continuously over a period consisting of clear and cloudy days. If only instantaneous measures are possible, values should be obtained for both uniformly overcast and clear days.

Examples of the diurnal variation in light under a
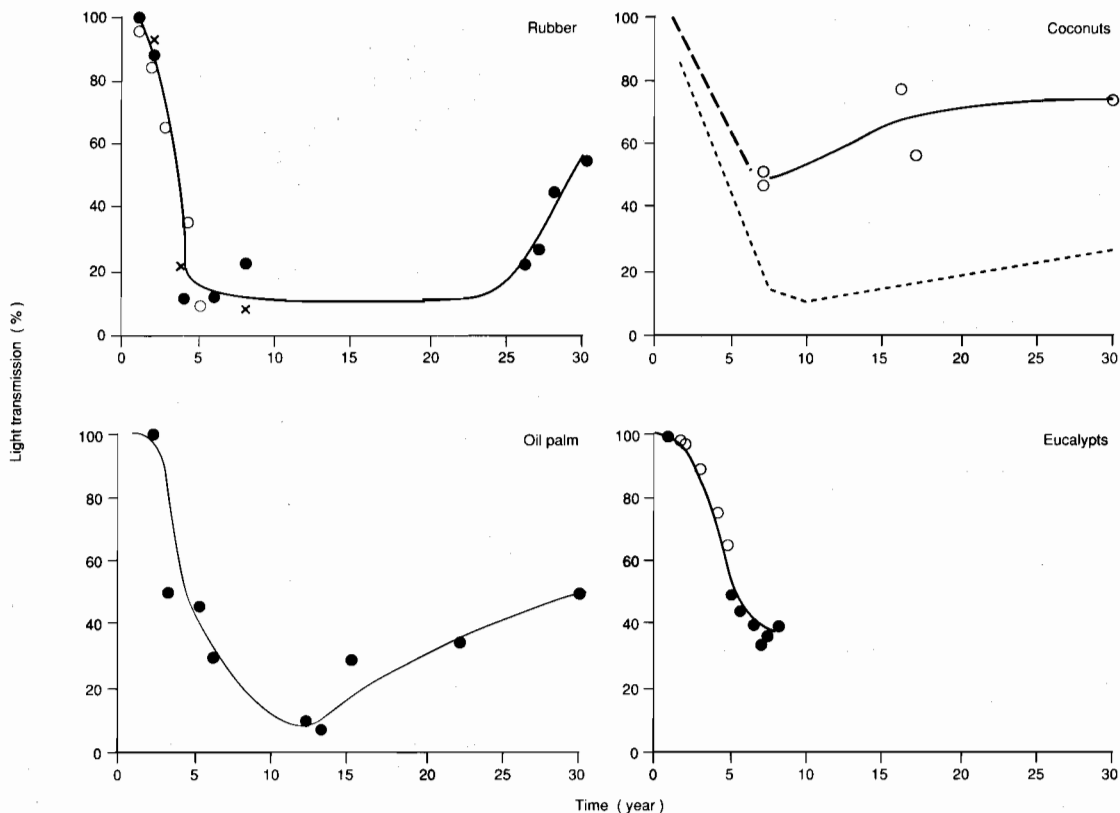
**Fig. 1.** Relative light transmission (%) profiles of photon irradiance with age for plantations of rubber (Chen 1989 |o|; Y.K. Chee and F.Md.A. Ahmad |x|, unpublished data; J.P. Evenson |o|, see Sophanodora 1989), oil palm (Chen 1989), coconuts (data summarised from Reynolds 1988 by H.M. Shelton, and theoretical curve |.....| by Nelliat et al. 1974), and eucalypts (*E. grandis* |o| Charles-Edwards, unpublished data; *E. deglupta* |o| Shelton et al. 1987b; the latter data was obtained using an integrating pyranometer measuring PI around midday).

tree canopy in a mid position between the tree rows are shown in Fig. 2. This can be expressed as relative PI transmission or as actual PI. The latter expression (Fig. 2b) is much more useful. Integration of the areas under the curves will give the average percentage of incoming radiation incident on the pasture over the whole day; it is seen from Fig. 2 that these values are lower than the peak transmission near midday. The area under the curve can also be used to calculate the average PI intensity over the day, and this then can be calculated to give a total PI input for the day. For example, for a 12-hour day and an average PI intensity of 1000 µmoles/m²/sec for the day, then PI input is

$$(1000 \times 3600 \times 12) / 10^6 = 43.2 \text{ Moles/m}^2/\text{day}$$
$$43.2 \times 0.23 = 9.94 \text{ MJ/m}^2/\text{day}$$

An example of spatial variation for 5.5-year-old oil palm ( Chen and Bong 1983) measured near midday is given in Fig. 3. Transmission ranges from 73% in the

middle of the interrow to 2.5% at the base of the stem. The area under this curve can be integrated to give an average relative light transmission to the pasture area over the whole interrow area under the trees (e.g. for the example in Fig. 3 the integrated value equals 47% of the light transmission measured at the centre of the row). Presuming the curve is not altered greatly with time of day, this information can be combined with the diurnal light input (from the central position between rows) to give an average daily light input over the whole pasture area. The problem is that few data sets are available to allow such calculations for many plantation ages and types.

The recent availability of small, inexpensive, hand-held integrating PI meters now enables the problem of spatial variability to be resolved more quickly and accurately. These instruments based on gallium arsenide phosphide photocells (Hamamatsu, Japan) are sensitive to the 300–680 nm range and can be

**Fig. 3.** Spatial variation in relative light transmission (%) in oil palm measured near midday (Chen and Bong 1983). The area under the curve has been integrated to give an average light transmission of 47%.
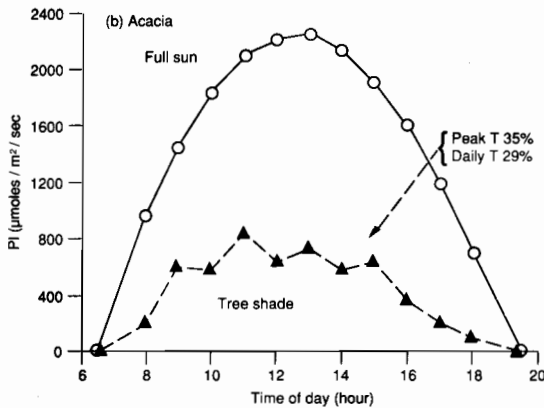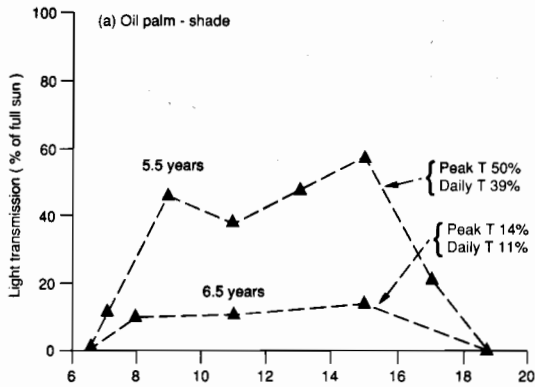
**Fig. 2.** Diurnal variation in light transmission for (a) oil palm – relative transmission of PI (%) under the canopy at two ages (adapted from Chen and Bong 1983, and (b) Acacia – PI above and under a canopy of 80% ground cover (from Ovalle and Avendano 1988). The area under the tree shade curves has been integrated to give the daily light transmission for comparison with the estimated peak transmission from a smooth curve fitted by eye to the points.

constructed of materials costing less than US$75. They can be programmed to integrate average PI over set time intervals, e.g. the operator can walk around within the plantation on a pattern to sample the spatial variation in light for, say, five minutes. Relative transmissions can be obtained using a second instrument operating outside the plantation at the same time.

## Temperature under the tree canopy

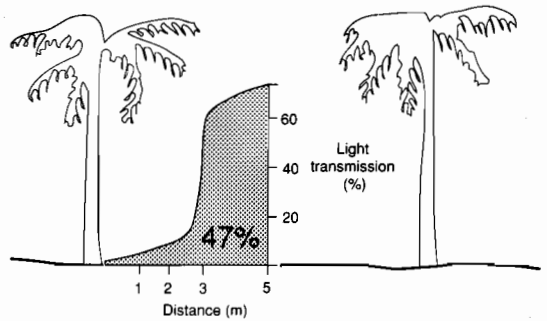The air temperature above the pasture under mature rubber trees is about 2–3°C lower at midday than above pasture in the full sun (Chen 1989). Ovalle and Avendano (1988) found air temperatures under an *Acacia* tree canopy to be 2–3°C lower for the maximum and 1.5–2°C higher for the minimum than

in the open. Studies with artificial shade show a similar small difference (1–2°C) in maximum or minimum air temperature and in leaf temperature between these two environments (Wong and Wilson 1980). Soil temperatures can differ much more, and may be as much as 10°C lower under the tree canopy than in the open at the soil surface (Wilson and Wild 1990, these Proceedings) or 3–10°C at a depth of 2.5 cm (Ovalle and Avendano 1988). At lower depths, the differences are much smaller, about 1–2°C.

While the differences in air and leaf temperature are probably too small to have any important influence on pasture growth in a tropical environment, the substantial amelioration of surface soil temperatures by the tree canopy may be important for better seedling survival, soil water relations and possibly rate of litter breakdown and nitrogen mineralisation (Wilson and Wild, these Proceedings).

## Humidity, evaporation and soil water under the tree canopy

Air relative humidity under the tree canopy is likely to be increased compared with that in the open or above the tree canopy; under artificial shade the maximum increase was about 6% (Wong and Wilson 1980; Wong et al. 1985a) over that in the open. Decreased radiation load under the shade of tree canopies should benefit the water relations of the pasture species. Leaf water potentials are higher in plants under shade than in full sun (Wong and Wilson 1980). Evaporative demand will be greatly reduced in the shaded environment, e.g. under acacia trees (Fig. 4a), and soil water availability for the pasture will be maintained at a higher level than in the open (Fig. 4b, and Wilson and Wild, these Proceedings) through the combined effects of less evaporation from the soil and lower transpiration rates of the pasture. These effects may lessen the periods when growth of pasture is restricted by soil water deficits during the dry season.
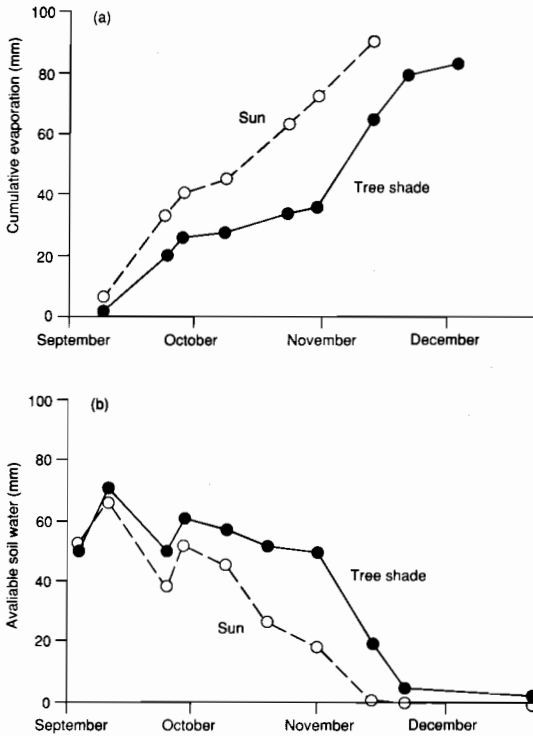
**Fig. 4.** Evaporation and available water content of the soil under the canopy of a plantation of *Acacia caven* (80% ground cover) and in the full sun (adapted from Ovalle and Avendano 1988).

However, the question of whether introduction of higher-performing pasture species into plantations to replace the natural vegetation will provide greater competition with the trees for soil moisture is unanswered at present. The review of coconut research by Reynolds (1988) suggests such an effect may be present in lower rainfall regions but not where annual rainfall exceeds 2000 mm. It is evident that this is an area which needs research to understand whether soil water changes under trees might lead to competition between understorey and tree, and reduced crop yield.

## Growth Model

In considering plant response to shade and the constraints imposed on pasture performance by the reduced light under plantations, it is helpful to refer to a simplified growth model so that useful plant attributes might be assessed:

$$G = n E_w J - V \tag{1}$$

This model adapted from Charles-Edwards (1982) expresses rate of growth of above ground herbage (G) as a function of the partitioning coefficient for distribution of biomass to tops (n), the efficiency of light utilisation for photosynthetic accumulation into whole plant biomass ($E_w$), the amount of PI intercepted over a given time interval (J), and the loss of biomass (V) over the interval.

Because $E_w$ is rarely, if ever, measured for pasture species this equation can be simplified to:

$$G = E J - V \tag{2}$$

where E is the efficiency of light utilisation for photosynthetic accumulation into above-ground herbage. The term E incorporates n and, as will be shown later, it can be determined directly from field experiments.

In a physiological sense E can be considered as:

$$E = ( P - R ) / J \tag{3}$$

where P is the mean gross rate of canopy photosynthesis and R is the mean dark respiration over the growth interval.

## Partitioning coefficient (n)

Even though n need not be measured to use equation (2), it is discussed here because it can be greatly modified by shade and this has important implications for pasture regrowth and survival. A substantial increase in shoot to root ratio is a usual adaptive response to decreasing light in both grasses and legumes (Table 3), with variation between species in the extent of the response (Wong et al. 1985a,b; Samarakoon et al. 1990).

Selection for excessive adaptation in this characteristic could lead to difficulties where periodic severe water stresses occur and where grazing pressure is high. Plants may be susceptible to being pulled out of the ground, and regrowth might be limited because of reduced carbohydrate or mineral reserves in the crown and roots. Under full sunlight, recovery of growth after defoliation may be more dependent on residual leaf area than on stored reserves (Humphreys and Robinson 1966). Under shade this situation may be reversed, because other morphological responses to shade such as increased stem elongation and reduced branching may result in little leaf area and few axillary growing points remaining after grazing. Clements (1989) points out

**Table 3.** Change in shoot–root ratios of tropical grasses and legumes grown at different light levels. Data from 12 grasses and 14 legumes (adapted from Wong et al. 1985a,b)

| Range for | 100 ⟶ 27% light | Relative increase |
|---|---|---|
| Grasses | 2.5 ⟶ 6.7 | × 2.8 |
| Legumes | 6.5 ⟶ 14.3 | × 2.2 |

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that the latter is a reason for poor tolerance to grazing of climbing and trailing tropical legumes even for pastures in full sun. This effect is likely to be exacerbated under shade. Carbohydrate reserves will thus be important for initiating new bud development. The capacity for accumulation of carbohydrate reserves in tropical pasture species is generally low, particularly for the grasses, because of their physiological characteristics (Wilson 1984), and this capacity is further diminished under shade (Wilson 1982). Therefore consideration perhaps should be given to those species of grasses and legumes with larger reserves of biomass in roots and/or rhizomes and stolons, which escape grazing. These species may be more tolerant of high grazing pressure (Wilson 1984), and they may be more persistent under dense shade than erect species that maximise leaf area production. However, prostrate species may have a more conservative growth performance under better light conditions. This seems to be borne out by the results of species testing given in this workshop. Stoloniferous species such as *Axonopus compressus*, *Brachiaria miliiformis*, *Paspalum conjugatum* and *Stenotaphrum secondatum* are reported to perform well in grazed pastures under shade (Rika et al. 1981; Watson and Whiteman 1981; McFarlane and Shelton 1986; Chen and Othman 1984). Prostrate legume species need to be evaluated in this context.

## Radiation use efficiency (E)

This may be considered in relation to the light response curves for leaf or canopy photosynthesis and respiration, or measured empirically in the field from the relation of herbage yield to amount of intercepted PI. The former is considered first.

### Photosynthetic rate (P)

The comparative light response curves for leaf photosynthesis of C4 tropical grasses and C3 tropical legumes is well known (Fig. 5a). The legumes become light saturated at low PI and thus P is relatively less affected by shade than in the grasses. However, light is not a determinant of photosynthetic efficiency until PI levels below about 200 µmoles/m$^2$/sec are reached. It is the slope of the tangent to the photosynthesis curve in this region that measures light use efficiency or quantum yield (CO$_2$ fixed/ unit absorbed PI). In warm environments at very low PI levels, the quantum yield of these two groups is relatively similar or slightly higher for C4 grasses than for C3 tropical legumes (Bjorkman 1981; Ludlow 1981). Thus, although C4 photosynthesis is decreased relatively more than C3 photosynthesis as light decreases, there is no reason to believe that C3 legumes will be inherently more efficient and have an advantage at low light levels. This view is sustained by ecological observations of species frequency in low light habitats
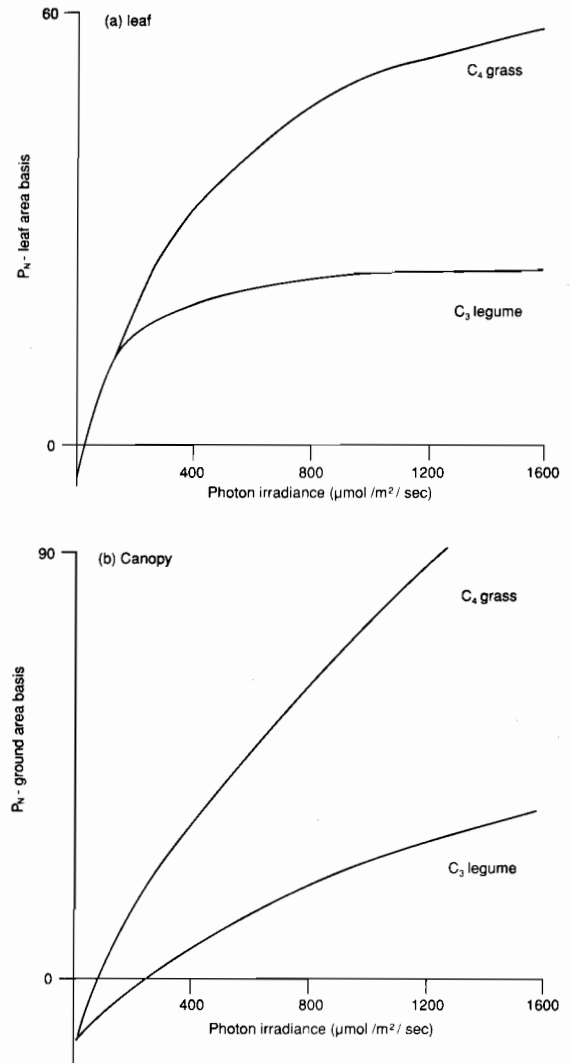


**Fig. 5.** Light response curves for net photosynthesis of a tropical C4 grass and tropical C3 legume for (a) individual leaf: *Pennisetum purpureum* and *Calopogonium mucunoides* (after Ludlow 1982), and (b) whole canopy: *Zea mays* (Alberda et al. 1977) and *Arachis hypogea* (Boote et al. 1980).

(Bjorkman 1976; Winter et al. 1982; Ehleringer and Pearcy 1983). Thus it appears that possession of the C4 photosynthetic pathway per se does not mean an inability to grow under heavily shaded conditions (Ludlow et al. 1974; Edwards et al. 1985). Competition for light appears to depend more on the leaves of a particular species gaining preferential access to the limiting factor (i.e. light) than on the photosynthetic response (Ludlow 1978).

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It is a common viewpoint that 'sun-adapted' tropical grasses are at a photosynthetic disadvantage to their shade-adapted counterparts when grown under dense shade. This view is not correct as seen in the comparison of Ward and Woolhouse (1986) between the 'sun' species *Zea mays* and the 'shade' species *Paspalum conjugatum* (Fig. 6). Even though leaf P of *Z. mays* is greatly reduced when grown at lower light levels, its value is still equivalent to that of *P. conjugatum* at the lowest light value. In fact, it is the corollary that is most often true, that true shade-adapted plants are unable to adapt to high light with an increase in P. This may have two consequences. Firstly, their yield potential at high light is poor and thus they are not suitable species for planting in young plantations to take advantage of the high light levels available at that time. Secondly, some species are unable effectively to dissipate absorbed light energy through greater photosynthesis at high light. This results in damage to the photosystem and in leaf necrosis, and is termed photoinhibition (Bjorkman 1981).

Another aspect of photosynthetic light response that is not widely appreciated is the greater linearity of the response for both C4 and C3 species when P is measured for the whole canopy (Fig. 5b) or whole plant (Fig. 7) compared to individual leaves (Fig. 5a). Thus yield decline with lower light is likely to be closer to linear than would be thought from consideration of leaf response curves. The latter are very commonly measured but only a few sets of data are available for canopy P of tropical pasture species. These studies are mainly for canopies in full sunlight (e.g. Ludlow and Charles-Edwards 1980; Ludlow et al. 1982). The limited study of Sophanodora (1989) provides the only data found for shade-adapted pastures.

*Respiration (R)*
As light levels decrease in more shaded habitats, the rate of dark respiration also decreases. This is clearly shown in the data of Ludlow et al. (1974) for whole plants (Fig. 7). The decrease in R as a percentage of gross photosynthesis from 100% to 10% light was
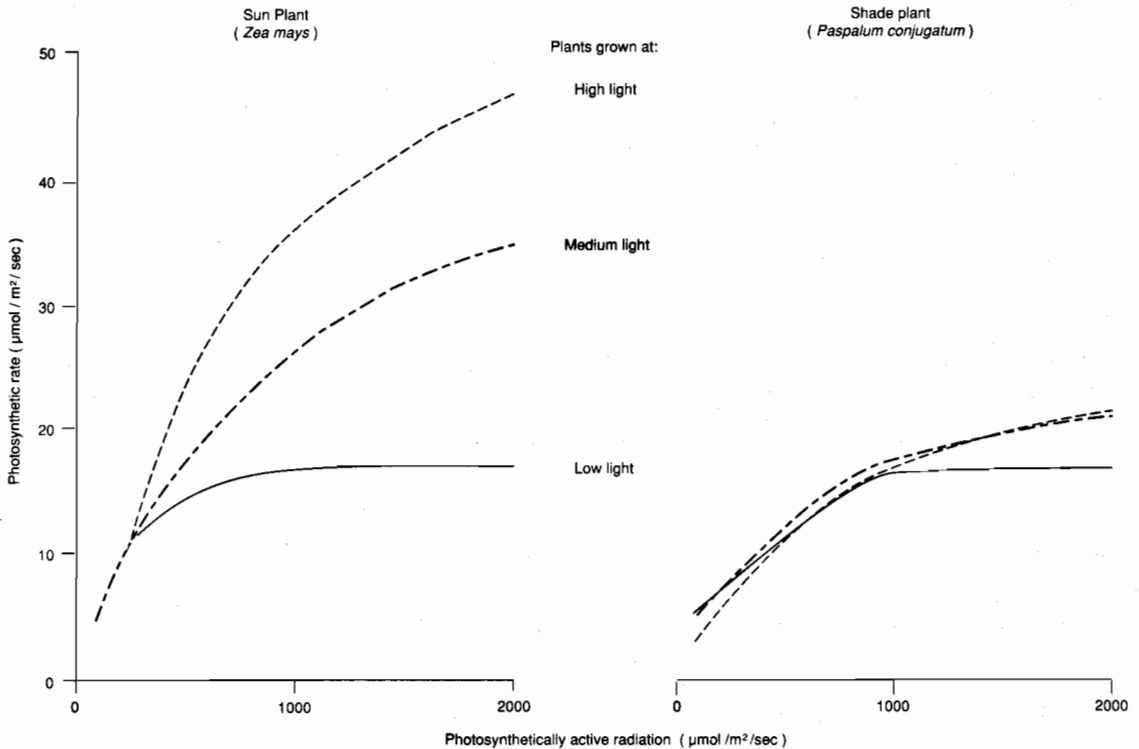


**Fig. 6.** Light response curves for leaf photosynthesis of a 'sun' plant (*Zea mays*) and a 'shade' plant (*Paspalum conjugatum*) grown at low, medium and high light levels (adapted from Ward and Woolhouse, 1986).

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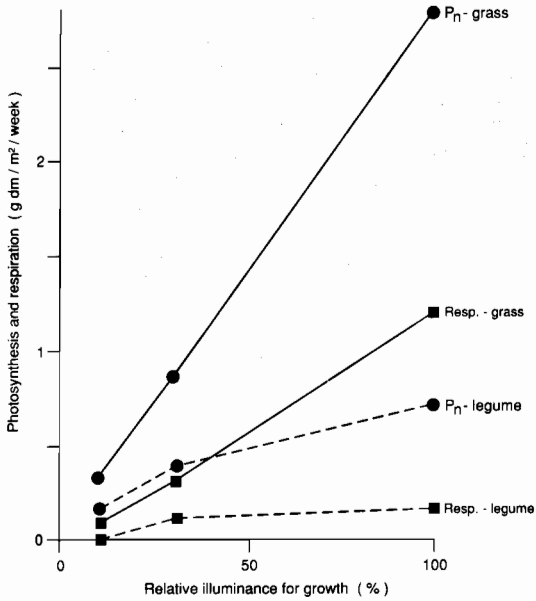**Fig. 7.** Whole plant photosynthesis and respiration for a tropical grass (*Panicum maximum* var. *trichoglume*) and legume (*Macroptilium atropurpureum*) grown at different light levels (after Ludlow et al. 1974).

from 43% to 26% in *P. maximum* and from 22% to 20% in *Macroptilium atropurpureum*. The two tropical grasses studied in this work appeared to show a greater adjustment of R than the two tropical legumes studied. The decrease in R is of paramount importance for plants at very low light (e.g. <10% sunlight) so that they can maintain positive carbon balance (Bjorkman 1981; Winter et al. 1982). An important attribute of true shade plants is that they can reduce R to a very low level (Boardman 1977).

Reduction of R allows for a decrease in the light compensation point LCP i.e. when the rate of $CO_2$ fixation equals the rate of $CO_2$ respired. For example, for leaf of *Paspalum conjugatum*, a shade-tolerant species, LCP decreased from 34 μmoles PI/m$^2$/sec at high light to 10 μmoles PI/m$^2$/sec at very low light (Ward and Woolhouse 1986). In the same study, the decrease in LCP for the sun-species, *Zea mays*, was much less (25 to 16) and the LCP at low light of 16 μmoles/m$^2$/sec much higher than for the shade-species. Canopy P and R measurements of tropical pasture species after adaptation to various levels of shade are not available. They would be particularly valuable to allow calculation of the minimum PI necessary to maintain a positive carbon balance and hence the maximum percent age of shade at which some pasture growth could be expected. It should be remembered in such calculations for the tropics that

photosynthesis occurs for only 12 hours a day and respiration for 24 hours. If photosynthetic light response curves of the form in Fig. 5b were available for shade-grown canopies then the average daily PI for light compensation on a 24-hour basis could be estimated from these plots by assuming the respiration component was doubled and plotting a new curve parallel to the experimentally derived curve and estimating the new compensation point at zero P (see diagrammatic illustration in Fig. 8).
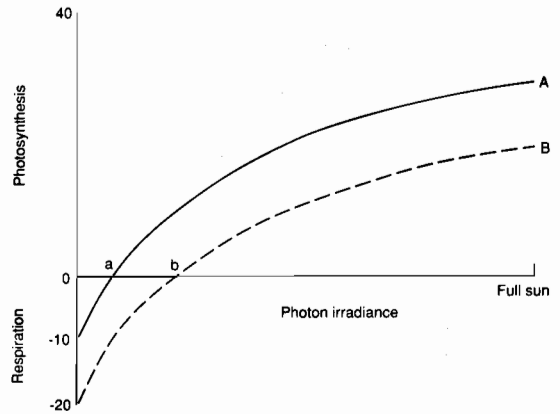


**Fig. 8.** Diagrammatic representation of the instantaneous photosynthetic light response curve of a shade-adapted pasture canopy (A) with light compensation point (a), and the adjusted curve (B) allowing for respiration 24 hours/day and photosynthesis for 12 hours. The value (b) is the average daily PI at which P is zero.

*Direct estimation of E*

Measurement of canopy P and R requires very expensive equipment available in few pasture research groups in the tropics. An empirical estimate of E integrating effects of P, R and n is more easily obtained from the slope of the linear relationship between herbage yield and accumulated intercepted PI (Fig. 9). Intercepted PI is measured using linear PI probes placed at ground level under the sward, and herbage yield determined by sequential harvesting. E is expressed as grams dry weight yield of herbage per unit of PI (g/MJ). The E value measured incorporates V (see equation (2)), i.e. refers to net biomass production. This procedure has been used often for crop species (e.g. Muchow 1985, 1989) but very few estimates are available for tropical pasture species, and as far as we are aware, only one set of data is available for pasture species under different light levels (viz. Sophanodora 1989). Some values for tropical crop and pasture grasses and legumes are given in Table 4.

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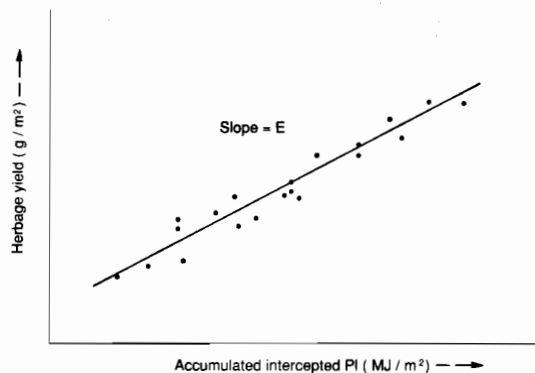
**Fig. 9.** Diagrammatic representation of the relationship between herbage DM yield and intercepted PI (based on Sophanodora 1989). Radiation use efficiency (E) is the linear slope.

Values of E for C4 grasses are substantially higher than for C3 legumes, and within each group there were some differences between species. Generally, these differences were less than those imposed by changes in growing conditions. Values were reduced under limitations of nutrients or water, and this would be expected from the decrease in P under these conditions. The most interesting effect from the point of view of pastures under plantations is that E increases substantially under lower light levels. Several features may explain this effect: more dry matter is partitioned to above-ground herbage (shoot to root ratio increases, see Table 3); leaf to stem ratio may increase (Table 5) thereby reducing light interception by less efficient stem tissue; leaf nitrogen concentration may increase (Samarakoon et al. 1990; Wilson and Wild, these Proceedings); and the leaves are less $CO_2$ - limited for photosynthesis.

These estimates of E are particularly useful for modelling potential pasture production under plantation systems, as will be discussed later. There is a need for more studies of tropical pasture under different shade levels to establish E values for some typical morphological types, e.g. examples of erect- and prostrate-growing sun and shade-tolerant species of grasses and legumes. If species differences are not large (as is suggested by data in Table 4) then such estimates could be widely applicable.

## Amount of intercepted radiation (J)

To compensate for reduced light under tree canopies, plants attempt to maximise leaf area through an increase in shoot–root ratio (Table 3) and in leaf–stem ratio and/or specific leaf area (area per unit leaf weight) (Table 5; Samarakoon et al. 1990). The comparative data of Wong et al. (1985a,b), which are

**Table 4.** Estimates of radiation use efficiency (E, g/MJ of PI) for some tropical pasture and crop grasses and legumes under (a) different levels of light and nitrogen, and (b) water stress

*Light and nitrogen*[a]

| Light level | Adequate N | | | Limited N | |
|---|---|---|---|---|---|
| | Guinea | Signal | Centro | Guinea | Signal |
| 100% (full sun) | 2.0 | 2.0 | 1.0 | 1.3 | 1.5 |
| 70% | 2.5 | 2.3 | 1.0 | 1.4 | 1.6 |
| 30% | 3.4 | 2.8 | 1.7 | 2.6 | 2.6 |

*Water stress*

| | Maize[b] | Sorghum[b] | Millet[b] | Grain[c] legumes |
|---|---|---|---|---|
| Irrigated | 2.4 | 2.1 | 1.9 | 1.4 |
| Water stressed | 1.6 | 1.9 | 1.8 | 1.1 |

[a] Sophanodora (1989): Guinea (*P. maximum*), signal (*Brachiaria decumbens*), centro (*Centrosema pubescens*)
[b] Muchow (1989): mean of 3 sowings
[c] Muchow (1985): mean of 7 types, range 1.2–1.6 (wet) and 0.8–1.2 (dry).

**Table 5.** Change in leaf–stem ratio and specific leaf area ($cm^2/g$) of tropical grasses and legumes with different light level; range for 12 grasses and 14 legumes (adapted from Wong et al. 1985a,b)

| | Leaf–stem ratio | | Specific leaf area | |
|---|---|---|---|---|
| | Range 100→ 27% light | Relative increase | Range 100→ 27% light | Relative increase |
| Grasses | 1.12→ 1.82 | × 1.6 | 171→ 354 | × 2.1 |
| Legumes | 1.24→ 1.21 | ×0 | 227→ 397 | × 1.8 |

summarised in Tables 3 and 5 , and that of Ludlow et al. (1974) indicate that, in general, neither grass nor legume group could be considered more responsive than the other. However, there are substantial differences between species within the grass or legume group in morphological plasticity in response to shade, which possibly could be exploited in species selection.

The ability to regenerate leaf area after defoliation, and maximise J, is a most critical factor influencing pasture production even under full sunlight (e.g. Clements 1989). It is even more critical under shade, and the loss of sown, erect pasture species in plantation crops with time has been attributed as much to their inability to recover from repeated grazing as to their inability to tolerate shade per se (e.g. Chen and Ahmad 1983). The progressive decline in regrowth yields of erect-type legumes with successive defoliations under shade conditions is clearly shown by Wong et al. (1985b). Similar responses are evident for grasses, as shown in the species testing trials

reported in this workshop. For most species, the adverse effects of shade will almost certainly be cumulative with successive grazings, so that for plants to survive non-grazing intervals must be lengthened as time and shading progresses. Species tolerant of close grazing will become particularly important under shade conditions, and the ability to retain some ungrazed leaf area may become vital to maintain J as high as possible.

While measurement of these morphological adaptations is relatively easy, incorporation of these changes into a model to predict their effect on J is somewhat more difficult. We believe a direct experimental measure of J is a more viable approach.

This can be done using linear PI probes placed above and below the sward. These can be connected to data loggers to record daily PI over any given time interval and thereby calculate per cent light interception (Muchow and Davis 1988). Alternatively, the probes can be measured manually at intervals over a day and the values integrated graphically to give a per cent light transmission for that day; this can be repeated at weekly intervals. Attention must be paid to keeping the probes

free of dust and moisture condensation. The relative light interception values can then be plotted against time from defoliation. An example of such data (Sophanodora 1989) for guinea grass and centro grown at 30% light and defoliated at 8- or 4-week intervals is given in Fig. 10. The proportion of incident light intercepted over the regrowth period can be obtained by integrating the area under the curve (e.g. 68% for guinea grass defoliated 8-weekly (Fig. 10). This can be converted to an amount of PI ($MJ/m^2$/day) intercepted, and hence an estimate of J using the output from the probe above the sward.

These types of measurements are reasonably common for crops, but they are rare for tropical pastures. We are aware of only one set of data for tropical pasture species grown under different levels of shading (viz. Sophanodora 1989). There is a need for more studies with some characteristic examples of erect and prostrate grass and legume species. Also, Sophanodora's pastures had experienced only two (8-week cut) or four (4-week cut) cycles of defoliation. Since regrowth capacity is likely to decline with more defoliations, as discussed above there is need to
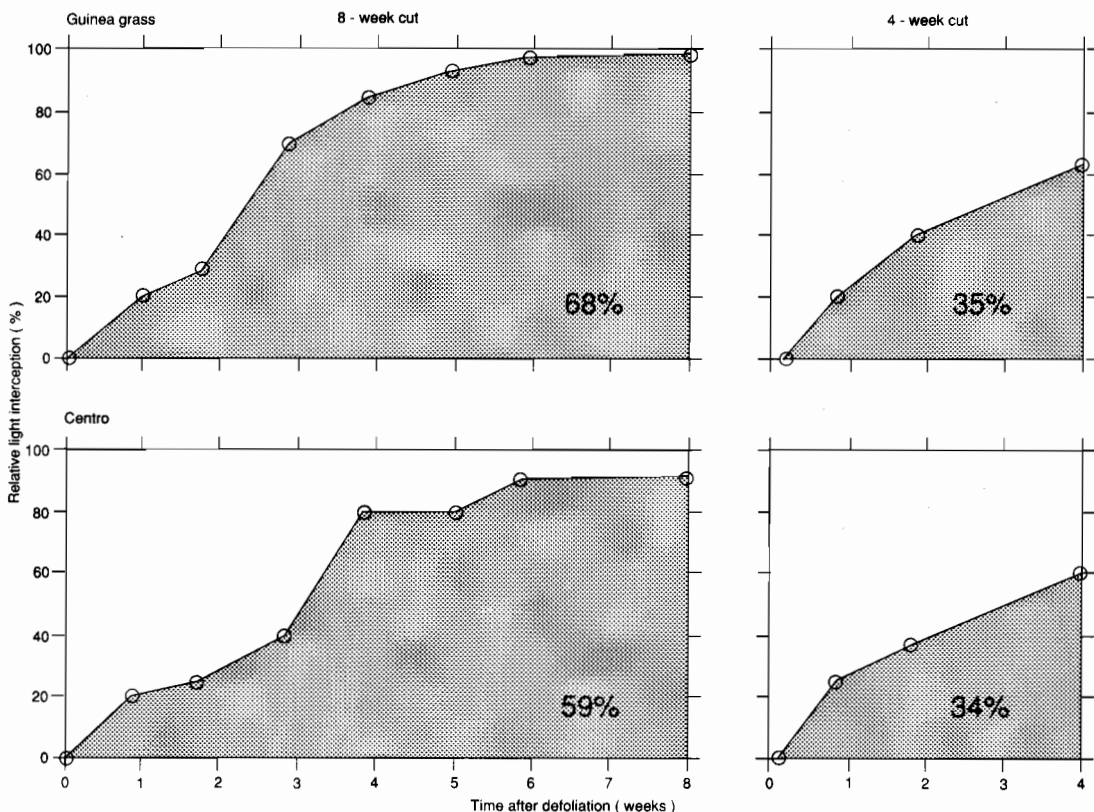


**Fig. 10.** Change in relative interception of **PI** with time for 8- and 4-weekly cut swards: guinea grass (*P. maximum*) grown at low to moderate nitrogen supply, and centro (*Centrosema pubescens*) (adapted from Sophanodora 1989).

examine pastures after a longer period of treatment to provide realistic estimates of J for older pastures under a plantation.

**Loss of biomass (V)**

This term may be particularly significant in pastures under older plantations. In these circumstances, standing biomass of understorey herbage may be only 500 kg/ha (Wan Mohamed 1977), and regrowth rates will be very low, so loss of leaf area through senescence, insect or fungal damage is of major importance. The wetter, more humid environment under the canopy of plantations increases the risk of fungal attack on the understorey species (Watson 1963; Grime 1966, 1981), and there is some evidence that shade-tolerant plants are more resistant to fungal infection than shade-intolerant plants (Grime 1966). Successful shade plants may develop defence mechanisms to reduce fungal or insect attack, and perhaps structural and other features that increase the natural longevity of their leaves. These adaptations could be counterproductive to their use as forage, because they may greatly reduce the palatability of the herbage to grazing animals.

There are no estimates of V which might be incorporated into models. Chen and Othman (1984) found that shade intolerant legumes (*C. pubescens, M. atropurpureum, Stylosanthes guianensis*) under 5–7-year-old oil palm, defoliated at long intervals of 8 or 12 months, had a lower accumulated yield over two years than when defoliated every 4 months, whereas this was not so for the shade-tolerant species, *C. caeruleum* and *D. ovalifolium*. This suggests that the latter may have had a lower loss of biomass in old swards.

## Estimate of Pasture Growth Rate under Plantations

Such estimates can be made quite simply and should prove very useful in providing an assessment of potential grass or legume production under any particular light level. The potential for pasture production can then be compared with animal herbage requirements and the likelihood of sustaining a grazing capacity assessed for any particular age of plantation.

The growth model is simplified to:
$$G = E J \qquad (4)$$
where G is growth rate of herbage in $g/m^2/day$, E is radiation use efficiency in g/MJ of PI, and J is average amount of PI intercepted over any chosen time interval in $MJ/m^2/day$.

Two examples are worked through using data for incident light levels presented in the paper, and estimates of E and J for 8-weekly defoliated guinea grass and centro from Sophanodora (1989). The latter

data are from experiments at Redland Bay, Brisbane, Australia on a krasnozem soil at low to moderate nitrogen fertility for the grass. The plantation light level is based on the diurnal variation given for a 6.5-year-old oil palm shown in Fig. 2a, and the spatial variation in Fig. 3.

*Example 1: Guinea grass at low–moderate N level under oil palm with 14% light transmission at the row centre at midday.*

| | | |
|---|---|---|
| i) | Daily SW radiation above trees (e.g. Ciawi, Indonesia) | $16\ MJ/m^2/day$ |
| ii) | Average daily light transmission % under trees at row centre (see diurnal integral, Fig. 2a) | 11% |
| iii) | Average proportion of the above seen by pasture for whole interrow area (accounts for spatial variation, Fig. 3) | 47% |
| iv) | Average daily SW incident on pasture $(16 \times 0.11 \times 0.47)$ assuming that under trees, PI = 0.27SW | $0.83 MJ/m^2/day$ |
| v) | Average daily PI incident on pasture $(0.83 \times 0.27)$ (Assuming two-monthly regrowths intercept 68% of the incident PI (Fig. 10)) | $0.22\ MJ/m^2/day$ |
| vi) | Amount PI intercepted for growth $(0.22 \times 0.68)$ assuming radiation use efficiency, E = 2.6 g/MJ (Table 4) | $0.15\ MJ/m^2/day$ |
| vii) | Average daily growth rate of herbage DM $(0.15 \times 2.6)$ | $=0.39\ g/m^2/day$ $= 3.9\ kg/ha/day$ |
| viii) | Assuming 250 growing days/year, yearly production herbage DM | = 975 kg/ha |
| ix) | Assuming actual area available for pasture under rubber is only 66% of total area, yearly production per ha of plantation | = 644 kg/ha |
| x) | Assuming 40% leaf (Sophanodora 1989), yearly production of leaf DM | = 258 kg/ha |

*Example 2: Centro under the same conditions as for guinea.*

The following items will change:-
vi) Two-monthly regrowths intercept 59% of the

incident PI (Fig. 10); vii) radiation use efficiency, $E = 1.7$ g/MJ (Table 4); and x) assume 49% leaf (Sophanodora 1989).

The calculations become:-

| | | |
|---|---|---|
| vii) | Average daily growth rate of herbage DM | $= 0.22$ g/m$^2$/day |
| | | $= 2.2$ kg/ha/day |
| viii) | Yearly production herbage DM | $= 550$ kg/ha |
| ix) | Yearly production per ha of plantation | $= 363$ kg/ha |
| x) | Yearly production of leaf DM | $= 145$ kg/ha |

### Comments on the analysis

(a) The use of integrating PI meters as discussed in the text would allow the calculations to start at step (v). They would also avoid the difficulty of estimating the attenuation of PI relative to SW. In any case we are aware of no values for rubber, coconuts or oil palm.

(b) The estimate of proportion of incident PI intercepted will vary with the length of the regrowth interval considered (see Fig. 10). The value from Sophanodora (1989) was after only two defoliation cycles. Because it is expected that the regrowth will become slower with successive cycles, as discussed in the text, the values used in the analyses above probably substantially overestimate the proportion of PI intercepted in the regrowth of the old pastures, which would be present under the light level chosen. Thus the growth rates calculated represent the maximum potential to be achieved for a low to moderate nitrogen level. The E value will be higher for guinea at high nitrogen supply and light interception may also be higher.

(c) The number of growing days per year will vary from site to site, affected substantially by drought periods. Temperature should not be a limitation in most plantation areas.

(d) The area unavailable for pasture has been mentioned to be as high as 33% in rubber, and Reynolds (1988) mentions 12.5% for coconuts.

(e) Leaf DM available might be a better measure of potential for animal production than total pasture DM.

(f) The analysis takes no account of any loss of DM over the growth interval (i.e. V).

(g) The values for E come from Sophanodora (1989) and are for young pastures under shade; such high values may be difficult to sustain over periods of six months or more, and during flowering as opposed to vegetative growth stages.

## Comparison of Potential Pasture Growth with Animal Requirement

Calculations of the maximum potential for pasture growth at any chosen light transmission (age of plantation) can be compared with animal requirement for production. Allowance should be made for the appropriate level of soil fertility.

Pasture feed requirement for cattle can be estimated using tables in Minson and McDonald (1987). An example is that of a 300 kg steer gaining at the low rate of 0.25 kg/head/day, which requires an intake of 5.8 kg/day of herbage at 55% digestibility. This requirement is much higher than the daily growth rate of total herbage on one ha of guinea (3.9 kg/day) or centro (2.2 kg/day) grown under low light in a plantation 5–6 years old. The feed deficit would be even greater if the animals are considered to consume mainly leaf.

Pasture feed requirement for sheep was estimated for a 15 kg lamb growing at 100 g/day, assuming the lamb received 100 g palm kernel cake per day and pasture digestibility was 60%. The estimate (B.W. Norton, pers. comm.) was 0.69 kg/day (4.6% of bodyweight). Another type of estimate from the experimental work in this ACIAR project (Tajuddin Ismail, Chong D. T. and Abd. Samat, pers. comm. is that a lamb gaining at the maximum rate of about 110 g/day requires 270 kg/ha of edible feed on offer.

Thus the estimates of potential pasture production may be compared with the estimated requirements of animals to estimate the carrying capacity of plantations of various light transmissions, and therefore assess potential viability of an animal enterprise.

## Conclusions and Recommendations

This review highlights some of the problems associated with obtaining sustainable pasture production, and hence animal grazing, under the shade environment of plantation crops. The main environmental limitation is the reduction in photosynthetically active radiation (photon irradiance) incident on the pasture understorey. Whether competition for water between tree and pasture is a limitation for pasture growth is not known. However, by comparison with the situation in full sun, evaporation rate is reduced and soil water content is maintained at a higher level under the canopy of trees. Thus drought periods could be less severe under the tree environment. Air and leaf temperatures under trees differ little from those in the open, but soil surface temperatures can be much reduced. This may provide a more conducive environment for litter breakdown and nutrient turnover.

Most species of grass or legume adjust morphologically to compensate for increased shading as plantations grow. Generally, this is directed towards maximising the distribution of dry matter towards leaf area for light absorption. The inherent light use efficiency of these leaves for photosynthesis

at low PI levels differs little between the C4 (grasses) and C3 (legumes) types. For undefoliated plants under dense shade, morphological adaptations, reduced respiration and preferential access of leaves to the light are probably the most important factors for success, as is possibly also the capacity to minimise leaf loss or damage. Under grazing, the morphological adaptations in some species towards taller plants and greater leaf production may reduce too far root reserves and the number of buds remaining after defoliation. This would greatly weaken the regrowth capacity of these species. Prostrate species with rhizome or stolon reserves and leaf area escaping grazing may be more successful. This aspect needs evaluation under grazing.

A simple growth model can predict potential pasture growth rate with only a few inputs, viz. PI incident on the pasture, radiation use efficiency (E) of the pasture, and the proportion of radiation intercepted over any regrowth period (J). These parameters can be derived experimentally without a large research input, but for all three there is need of more data.

*PI on pasture under trees.*

Records in the readily accessible published literature are scant even for the major plantation crops. Suitable PI instruments are now available to give values integrated over time and space to replace the present light/age curves largely obtained by single time-of-day measures at a single position (mid-row).

What is then needed are some mathematical functions to relate the integrated measures to the single measure, because the latter is very cost- and time-efficient. Armed with this information the operator can convert a centre-row noon transmission to a daily PI integral for use in the growth model.

*Measures of E.*

Very few values are available for tropical pasture species, especially for swards adapted to shade. It is suggested that some effort should be put into obtaining such values of E for some representative species of prostrate and erect grasses and legumes. Determinations at high and low nitrogen supply would help define the limits of the E values.

*Measures of J.*

These should be obtained from the same experiments as those determining E, using linear PI probes to determine light interception. The major qualification is that pastures should have been established for some time and be measured over at least 4-6 defoliation cycles to assess the cumulative effect of repeated defoliations under shade.

The above information will be extremely valuable in providing a predictive capacity to extend the usefulness of site-specific species testing. For a particular plantation crop giving a known range of shade levels, the viability of an animal enterprise can be assessed initially, without experiment, by comparing the predicted maximum potential for pasture growth with the proposed animal requirement for feed.

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# Review of Forage Resources
# in Plantation Crops of Southeast Asia
# and the Pacific

### W.W. Stür* and H.M. Shelton*

## Abstract

Vast tracts of land in plantations in Southeast Asia and the Pacific sustain the growth of naturally occurring forages. The productivity of these forages under grazing is generally low, but most are persistent and well adapted to the local environmental and management conditions. No species is productive at light levels of less than 30% because of the limited production potential at low-light environments. In plantations with light transmissions of 30–50%, species such as *Axonopus compressus*, *Stenotaphrum secundatum*, *Ischaemum aristatum* and *Desmodium heterophyllum* are successful. At light levels higher than 50%, the more productive introduced species warrant consideration. A greater range of species is required which will persist and suppress weeds at moderate light intensities and low management levels.

A brief description of the principal species currently used for forage supply in plantation crops is given.

PLANTATION tree crops do not intercept all incoming light and consequently there is scope for the growth of natural vegetation or the cultivation of other useful introduced species.

From an animal production point of view, understorey natural vegetation can be divided into species which are eaten by ruminants and those which are unpalatable. In this context, the latter will be referred to as weeds while the 'eaten' species will be called forages. Undoubtedly, many plantation managers would use a different definition of the term weed.

The vast majority of available land in coconut, rubber and oil palm plantations is occupied by naturally occurring species. However, there are considerable areas of planted cover crops and very limited areas of planted forages.

This article describes the environment in which the three major plantation types (coconut, rubber and oil palm) occur, discusses the adaptation and value of the most frequently encountered naturally occurring and sown forage species, and reviews the potential for making best use of existing forage resources in plantation crops.

## Distribution and Habitat of Plantation Crops

The climatic and edaphic requirements of rubber and oil palm (Purseglove 1968, 1972) are somewhat similar, while coconut has different requirements (Table 1). Rubber and oil palm are grown mainly in the lowlands of the humid tropics, with high rainfall and no or only short dry seasons. While these crops can be grown on a wide range of soils they are usually found on acidic soils of low fertility.

Coconut, on the other hand, is grown chiefly along coastal belts in areas with an annual rainfall of 1300–2600 mm. Long dry periods are detrimental but can be tolerated where there is a good ground water supply. Long sunshine hours are required for high productivity. Coconut is grown on less acidic soils than rubber and oil palm, and is often found on alkaline and saline soils. The fertility of coconut soils varies from fertile volcanic soils to infertile coralline sands. The latter soils may be deficient in potassium (Macfarlane and Shelton 1986) and iron (Gutteridge 1978).

The root distribution of coconut and oil palm is similar with the majority of roots being concentrated within 2–3 m of the trunk (Purseglove 1972; Kushwah et al. 1973; Steel and Humphreys 1974), although some laterals occur. Roots of rubber are concentrated in the top soil layer with long laterals reaching into the interrows (Purseglove 1968).

The light environment under rubber and oil palm is similar with high initial light transmission at planting (>

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**Table 1.** Distribution and habitat of plantation crops.

| | Coconut | Rubber | Oil palm |
|---|---|---|---|
| Distribution | 20°N – 20°S | 15°N – 10°S | 10°N – 10°S |
| Altitude (m) | < 300 | Lowland | Lowland |
| Rainfall (mm/year) | 1270 – 2550 | > 1900 | > 1800 |
| Acceptable dry season | Short - medium | Short only | Short only |
| Required sunshine | Long | – | – |
| Humidity | High | Very high | – |
| Soil | Coastal belt (Wide range) | Wide range | Wide range |
| Soil pH range | 5 – 8 | 4 – 8 | 4 – 6 |
| Salinity | Tolerant | – | – |
| Required drainage | Excellent | Good | Adequate |
| Ground water supply | Required | – | – |
| Root distribution | Top 1.5 m, mainly within 2 m from trunk some laterals | Mainly top layer but long laterals 2 m from trunk | Top 15 cm, mainly within |
| Light transmission %* | | | |
| 0 – 5 years | 100 – 60 | 100 – 30 | 100 – 30 |
| 6 – 15 years | 60 – 40 | < 30 | < 30 |
| > 15 years | 60 – 80 | < 30 | < 30 |

* estimation
Source: Purseglove 1968, 1972.

90%); this declines to very low levels (10–20%) within 6–7 years and remains low until the trees are replanted at an approximate age of 25 years. The majority of coconut stands in the world are of the tall variety, in which light transmission is high initially, declines to around 40% at age 5–15 years, and then increases up to 80% in old coconut stands aged 60 years and over (see Figure 1, Wilson and Ludlow, these Proceedings). Dwarf and hybrid varieties allow less light to penetrate their canopies and light levels are much lower.

## Naturally Occurring Forage Resources

Many naturally occurring forage species are found in coconut, rubber and oil palm plantations in countries of Southeast Asia and the South Pacific. Some of the more important species are shown in Table 2. Both native and naturalised forages thought to have been present for many decades are included. Sown or planted species of more recent origin (some of which are now naturalised) are discussed in a later section.

Species which occur in all three plantation types, and in several countries, are *Axonopus compressus*, *Imperata cylindrica*, *Mimosa pudica* and *Paspalum conjugatum*. Their distribution includes both Southeast Asia and the South Pacific, which shows their ubiquitous nature and their ability to grow in a wide range of environmental conditions. Other species such as *Ottochloa nodosa, Mikania cordata* and *Asystasia* spp. are mentioned frequently in rubber and oil palm in Southeast Asia. There is also a large number of species observed under coconuts in the South Pacific some of which occur in Indonesia. Many of these may be adapted to the more alkaline coconut soils. The most widespread naturally occurring legume in natural vegetation in the South Pacific is *Desmodium heterophyllum* (Reynolds 1988).

The adaptation and value of the major naturally occurring forages are summarised in Table 3 (Bogdan 1977; Holm et al. 1977; Plucknett 1979; Steel et al. 1980; Macfarlane and Shelton 1986; Reynolds 1988). Some of these species are now discussed.

*Axonopus compressus* is renowned for its ability to withstand heavy grazing pressure and it has been reported to invade sown pastures which were not fertilised (Roberts 1970), which were overgrazed (Watson and Whiteman 1981), or where light levels were low (Chen et al. 1978). It is particularly valuable in heavily shaded situations (maybe less than 30% light transmission) where sown grasses cannot survive regular grazing (Reynolds 1988). Productivity of this grass is low and it is outyielded by more productive grasses in less heavily shaded areas, provided the level of management is sufficiently high to ensure persistence of the sown grasses (e.g. Smith and Whiteman 1983). It is well accepted by stock and produces moderate liveweight gains (Reynolds 1981), particularly if combined with naturally occurring legumes such as *Mimosa* spp. Nutritive value measurements indicate a high digestibility compared to *Pennisetum clandestinum* and *Stenotaphrum secundatum* (Samarakoon et al. 1990a).

**Table 2.** Natural vegetation occurring frequently in plantations.

| Species | Coconut | Rubber | Oil palm |
|---|---|---|---|
| **Grasses** | | | |
| *Axonopus compressus* | Indonesia (11) | Malaysia (3,5,10) | |
| | Solomon Islands (1,9) | | |
| | Thailand (2) | | |
| | Vanuatu (6) | | |
| *Brachiaria miliiformis* | Indonesia (12) | | |
| *Brachiaria mutica* | | Malaysia (3) | |
| *Chrysopogon orientalis* | Thailand (2) | | |
| *Cyrtococcum oxyphyllum* | | Malaysia (5) | |
| *Digitaria* spp. | Indonesia (11,12) | | |
| *Eremochloa ciliaris* | Thailand (2) | | |
| *Imperata cylindrica* | Indonesia (11,12) | Malaysia (5,10) | Malaysia (8) |
| | Papua New Guinea (4) | | |
| | Thailand (2) | | |
| *Microstegium ciliatum* | Thailand (2) | | |
| *Otochloa nodosa* | Thailand (2) | Malaysia (3,10) | Malaysia (8) |
| *Paspalum conjugatum* | Indonesia (12) | Malaysia (3,10) | Malaysia (8) |
| | Thailand (2) | | |
| | Papua New Guinea (4) | | |
| | Vanuatu (6) | | |
| | Solomon Islands (9) | | |
| *Pennisetum polystachyon* | Solomon Islands (9) | | |
| *Stenotaphrum secundatum* | Vanuatu (6) | | |
| *Themeda australis* | Solomon Islands (9) | | |
| **Legumes** | | | |
| *Calopogonium mucunoides* | Solomon Islands (1,9) | | |
| | Papua New Guinea (4) | | |
| *Centrosema pubescens* | Solomon Islands (1) | | |
| *Desmodium canum* | Vanuatu (6) | | |
| *Desmodium heterophyllum* | Indonesia (11) | | |
| *Desmodium ovalifolium* | Thailand (2) | | |
| *Desmodium triflorum* | Indonesia (11) | | |
| *Mimosa pudica* and *M. invisa* | Solomon Islands (1,9) | Indonesia (12) | Malaysia (10) |
| | Vanuatu (6) | | |
| | Western Samoa (13) | | |
| **Broadleaf species** | | | |
| *Asystasia* spp. | | Malaysia (3,7) | Malaysia (8) |
| *Mikania cordata* | | Malaysia (5,10) | Malaysia (8) |

Sources :- (1) Watson and Whiteman, 1981; (2) Manidol, 1983; (3) Ani Arope et al., 1985; (4) Hill, 1969; (5) Lee et al., 1978; (6) Macfarlane and Shelton, 1986; (7) Wong et al., 1989; (8) Chen and Othman, 1983; (9) Steel et al., 1980; (10) Wan Mohammed, 1978; (11) May, 1977; (12) Rika et al., 1981; (13) Reynolds, 1981; (14) Plucknett, 1979; (15) Holm et al., 1977; (16) Reynolds, 1988; and (17) Bogdan, 1977.

*Paspalum conjugatum* has a similar distribution to *A. compressus* but grows best on more acidic soils. While it can withstand moderate grazing it disappears under continuous high grazing pressure. In the South Pacific, it is less productive than *A. compressus* (Smith and Whiteman 1983). It is less readily accepted by stock than *A. compressus* and is generally regarded as a grass of low nutritive value.

*Mimosa pudica* is often regarded as a weed because of its spiny stems, but it is readily accepted by stock and high animal weight gains have been recorded (e.g.

Partridge 1979; Reynolds 1981). It combines well with sward-forming grasses such as *A. compressus* and can withstand heavy grazing. Because of its spiny stems it is not usually recommended in sown pastures but it can form a useful component in naturally occurring swards (Reynolds 1988).

*Desmodium heterophyllum* is a perennial prostrate creeper which occurs throughout the South Pacific and Southeast Asia. Its success is related to its ability to withstand very heavy grazing pressure, and its shade tolerance (Reynolds 1988). While low-yielding,

it can improve animal production when a component of grass pastures and is therefore a valuable component in any pasture. Except for coralline sands, it is adapted to a wide range of soils (Steel et al. 1980). Although a good seeder, mechanical harvest of seed is difficult and no commercial seed is available. However, it can be propagated vegetatively.

*Imperata cylindrica* is regarded as one of the worst weeds in the region (Holm et al. 1977), as it is often not readily accepted by stock. However, Falvey (1981) in a review of *I. cylindrica* concluded that it is underrated as a forage resource. It can support low rates of animal weight gain, particularly when grazed young or associated with a legume. It cannot withstand heavy grazing pressure and is seldom found in heavily shaded situations. Growth of this species is best on fertile soils but it is also found on poorer soils. Replacement with other more productive and nutritious grasses, particularly in intensive grazing systems, is generally recommended.

*Ottochloa nodosa, Mikania cordata* and *Asystasia* spp. occur frequently in rubber and oil palm plantations of Southeast Asia. All of these are readily eaten by stock (Ani Arope et al. 1985) and can contribute to animal production. A high feeding value has been reported for *Asystasia* spp. (Wong et al., 1989) and *M. cordata* (Ginting et al. 1987). All three species occur at varying light levels but are susceptible to regular grazing at low light levels. It is difficult to generalise on animal preference. For example, Pillai et al. (1985) found that the proportion of *A. intrusa* increased under sheep grazing in immature rubber while *O. nodosa* decreased. On the other hand, Rosley Abdullah (1985) observed that sheep grazed *A. intrusa* before *O. nodosa* and *M. cordata* in a slightly older rubber plantation.

Other herbaceous legumes which occur in some coconut areas include *Desmodium triflorum, Desmodium canum* and *Alysicarpus vaginalis*. Of these, *D. triflorum* is probably the most widespread legume but, because of its very low growth form and productivity, contributes little to animal production.

## Sown or Planted Forage Species

There has been a long history of the use of legume cover crops in rubber, oil palm and, to a lesser extent, in coconut plantations. The planting of 'improved' forages for animal production has so far not been practised in rubber and oil palm except on an experimental basis, while there are some examples of commercial 'improved' pastures under mature coconuts.

### Cover crops
Cover crops are planted to suppress weeds, control soil erosion and to add nitrogen to the plantation crop.

Commonly used species are *Calopogonium mucunoides, Calopogonium caeruleum, Pueraria phaseoloides* and *Centrosema pubescens* (Plucknett 1979; Chee 1981). These are usually sown shortly after the planting of the plantation trees and dominate the interrow area for several years. As the light level decreases, naturally occurring species invade.

A summary of the adaptation and value of these cover crops as forages is presented in Table 3.

Chee (1981) described the succession of these covers when grown in combination and without grazing in young rubber. *Calopogonium mucunoides* dominates for the first year and then *Pueraria phaseoloides* in the second and third years. As light levels decrease further, *C. caeruleum* and *Centrosema pubescens* dominate and these latter two species will persist longer. When grazed by sheep, the proportion of *Calopogonium caeruleum* has been observed to increase while that of *P. phaseoloides* and *Centrosema pubescens* decreased (Pillai et al. 1985). This low acceptability of *Calopogonium caeruleum* has also been noted for cattle (Middleton and Mellor 1982). In a feeding trial with sheep and goats, Ginting et al. (1987) found that the digestibility of both *P. phaseoloides* and *C. caeruleum* was high, but the intake of *C. caeruleum* was low. A similar low intake by sheep of *C. mucunoides* has also been recorded (McSweeney and Wesley-Smith 1986).

Animal production from pastures containing *Centrosema pubescens* and *P. phaseoloides* has been excellent (Reynolds 1988). Both types require careful management to ensure persistence, a feature common to most twining, scrambling forage legumes. *Centrosema pubescens* can withstand moderate grazing pressure, while *P. phaseoloides* pastures can only be grazed lightly. *Calopogonium mucunoides* has persisted under moderate grazing pressure (cattle) under 60% light transmission coconuts in the Solomon Islands (Watson and Whiteman 1981).

### Introduced forage species
Although many of the common 'improved' pasture species have been tried experimentally under coconuts, particularly in the South Pacific, only a few species are in commercial use.

The major problem encountered with many introduced forage species is lack of long-term persistence. There are many examples of excellent initial growth of highly productive species, but soon naturally occurring species (particularly unpalatable weeds) invade and the planted species disappear. There are, however, some examples of introduced species which have persisted for many years and which may be regarded as naturalised in some areas. These include *Stenotaphrum secundatum* and *Ischaemum aristatum* in the South Pacific and possibly *Brachiaria decumbens* in parts of Southeast

**Table 3.** Summary of adaptation of frequently occurring forages.

| | Tolerance to shade | Forage yield | Animal product. | Required Management level | Required Soil fertility | Resistance to Grazing | Resistance to Drought | Resistance to Soil acidity | Resistance to Water logging | Weed invasion | Fertilizer response | Potential competition with plantation crops |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Naturally occurring** | | | | | | | | | | | | |
| *Axonopus compressus* | H | L | M | L | L | H | L | H | M | M | M | L |
| *Paspalum conjugatum* | H | L | L | L | L | M | L | H | H | L | L | L |
| *Imperata cylindrica* | M | L | L | – | M | L | H | H | H | – | M | M |
| *Mimosa pudica* | H | L | M | L | L | H | – | – | – | – | – | L |
| *Desmodium heterophyllum* | H | M | H | L | L | H | H | M | H | – | – | L |
| **Cover crops** | | | | | | | | | | | | |
| *Calopogonium mucunoides* | M | H | L | M | L | L | L | H | M | L | L | L |
| *Calopogonium caeruleum* | H | M | L | L | L | – | – | H | – | L | – | L |
| *Pueraria phaseoloides* | M | H | H | H | L | L | M | H | M | L | M | L |
| *Centrosema pubescens* | H | M | H | M | L | M | M | H | L | M | M | L |
| **Sown or planted** | | | | | | | | | | | | |
| *Stenotaphrum secundatum* | H | M | M | L | M | H | – | – | M | H | – | L |
| *Ischaemum aristatum* | H | M | M | M | L | M | – | M | M | H | M | L |
| *Brachiaria decumbens* | M | H | H | M | M | M | M | M | M | M | H | M |
| *Brachiaria humidicola* | M | H | H | L | M | H | H | M | H | H | H | M |
| *Panicum maximum* | M | H | H | H | H | L | M | M | L | L | H | H |

L = low, M = moderate, H = high

Asia although this latter species has not persisted in coconut plantations of the South Pacific. The most successful sown forages have been included in the agronomic summary in Table 3. Apart from being well adapted to the environmental conditions, these species keep out weeds and can withstand quite high grazing pressures.

As far as legumes are concerned, there are few examples of successful species. *Desmodium heterophyllum* and *Centrosema pubescens* are probably the most widely used herbaceous species. There are also some tree legumes such as *Leucaena leucocephala* and *Gliricidia sepium* which are persistent and highly productive under older coconuts. The most successful introduced species are now discussed.

*Stenotaphrum secundatum* is a low-growing stoloniferous grass which was planted in Vanuatu more than 40 years ago and, at low light levels, is considered more productive than *Axonopus compressus* or *Paspalum conjugatum* (Macfarlane and Shelton 1986). Its vigorous growth habit ensures relatively weed-free swards even at high grazing pressure but it combines with herbaceous legumes such as *D. canum, Mimosa pudica* and *Vigna hosei* at lower stocking rates. Animal production from pure *S. secundatum* pastures is low but can be expected to improve when combined with herbaceous or tree legumes (Macfarlane and Shelton 1986). *Stenotaphrum secundatum* is easily propagated vegetatively but produces no or little viable seed. The

digestibility and intake of *S. secundatum* is similar to *P. clandestinum* (Samarakoon et al. 1990b) and it appears to be an accumulator of sodium (Macfarlane and Shelton 1986).

*Ischaemum aristatum* is a low-growing, stoloniferous grass which has a higher yield than *S. secundatum* at light transmission levels of greater than 40%. It tolerates high grazing pressure and moderate liveweight gains have been reported (Reynolds 1988). It combines well with herbaceous legumes such as *D. heterophyllum* and *Centrosema pubescens*. It is established from cuttings and can be grown on infertile and fertile soils of medium to heavy texture (Steel et al. 1980). At higher light levels (>70%), other grasses such as *Brachiaria decumbens* are capable of producing higher animal production.

*Brachiaria decumbens*, a medium-height stoloniferous grass, is capable of producing very high dry matter yield at light levels of more than 70%, when grown on moderately fertile soils (Reynolds 1988). It can withstand heavy grazing pressure and produce high liveweight gains, particularly when mixed with legumes. Because of its vigorous growth habit it is difficult to maintain herbaceous legumes with this grass, especially at high grazing pressures (Macfarlane and Shelton 1986). It can be established from seed or vegetatively, but vegetative propagation is more difficult than for *S. secundatum* or *I. aristatum*.

*Brachiaria humidicola* is a strongly stoloniferous grass with an adaptation similar to *B. decumbens*, but

it does particularly well on alkaline coralline soils (Macfarlane and Shelton 1986). It can withstand a higher stocking pressure than *B. decumbens* and, although less readily accepted by cattle, it has been reported to produce reasonable liveweight gains (Reynolds 1988). As with *B. decumbens*, a major difficulty is the maintenance of companion herbaceous legumes. On the other hand, its vigorous habit suppresses weed growth. This species is widely used in Fiji and can be propagated easily by cuttings.

*Panicum maximum* cultivars have been used for grazing under coconuts in some areas. Plucknett (1979) considered the cultivars Petrie (Green Panic) and Embu (Creeping Guinea) to be the two most promising cultivars. These grasses combine well with legumes and produce excellent liveweight gains (Macfarlane and Shelton 1986). However, careful management including moderate grazing pressure and regular fertilisation is also required. Overgrazing or lack of fertilizer leads to weed invasion and the loss of the sown grasses.

Other grasses which are used to some extent under coconuts are *Brachiaria miliiformis* and *B. mutica*. The popularity of the latter species is related to its ease of establishment from cuttings, and its high yield and quality. However, it is not shade-tolerant and suitable only in very old coconut plantations in wetter areas (Reynolds 1988). *Brachiaria miliiformis* is used extensively in Sri Lanka but has been prone to disease attack in the more humid tropics (Reynolds 1988). It has been reported to be more shade-tolerant than other *Brachiaria* spp.

The legumes *Centrosema pubescens*, *Desmodium heterophyllum*, *Puearaira phaseoloides* and *Calopogonium mucunoides* have been described already. Other herbaceous legumes used to some extent include *Macroptilium atropurpureum*, *Desmodium intortum* and *Neotonia wightii*. All of these require careful management and will not persist when overgrazed.

*Leucaena leucocephala* and, to a lesser extent, *Gliricidia sepium* are used as a feed supplement to grazed pastures under coconuts. The prospects of *L. leucocephala* have diminished with the arrival of the leucaena psyllid but tree legumes in general have excellent prospects for integration into plantation systems. Their main advantage is their persistence, even under heavy grazing, where it is often difficult to maintain herbaceous legumes.

## Conclusions

There is quite a range of species naturalised under the various environmental regimes of plantation crops. However, no species can be recommended for light levels of less than 30% because of the limited production potential of very low-light environments.

In plantations with light transmissions of 30–50%, species such as *Axonopus compressus*, *Stenotaphrum secundatum*, *Ischaemum aristatum* and *Desmodium heterophyllum* may be suitable. Only when light levels are higher than 50% do more productive species warrant consideration.

At low management levels (high stocking pressure, no fertilizer, etc.), persistence and suppression of weeds usually requires an aggressive grass such as *Stenotaphrum secundatum*. Unfortunately, the ability to suppress weed growth usually means incompatibility with most useful herbaceous legumes. The most successful herbaceous legumes for combining with aggressive grasses are *Desmodium heterophyllum* and *D. triflorum*. Tree legumes may also play an important role in improving the feeding value of such pastures. Under higher levels of management, excellent levels of animal production can be achieved with highly productive sown grass/legume swards, particularly at light levels of 70% and above.

Despite the plethora of naturally occurring species available for reduced light situations, a greater range of grasses and legumes is required which will persist and contribute to annual production in low management and input systems.

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# Forage Resources in
# Malaysian Rubber Estates

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### Abstract

A survey of forage resources was undertaken in three age groups of rubber (1–2, 3–5 and 6–10 years) in five estates in the central region of Malaysia. Standing forage dry matter declined from 2600 kg/ha in young rubber to just over 500 kg/ha in mature plantations. Botanical composition varied with age of rubber and therefore light transmission. *Pueraria phaseoloides* was the dominant species in the interrows during the first 1–2 years. In 3-5 years old rubber the dominant plant species were the volunteer grass *Ottochloa nodosa* and the planted legume *Calopogonium caeruleum*. In 6–10 year old rubber ferns made up nearly 50% of the vegetation but volunteer grasses also contributed to the total biomass.

The Botanal method of sampling used in this study permitted the recording of larger numbers of samples in the field for yield and botanical composition than was possible using conventional systems of cutting and weighing quadrats.

In Malaysia, the area planted with rubber is estimated at 1.86 million ha (RRIM 1988). This vast cultivated area has tremendous potential for integration with livestock. To date sheep have proven to be very successful because their husbandry is sound economically and there is no requirement to clear new land purely for the purpose of growing pastures for animal production. The system maximises the use of agricultural land, provides returns from the sale of animals, and reduces the use of herbicides and the cost of weed control.

The amount and quality of forage resources have been shown to be important factors in sheep production under perennial crops of rubber and oil palm. Chen et al. (1978) reported that there were up to 60 different plant species in plantations, and 70% of these have been reported to be palatable to livestock (Wan Mohamed 1978). The age of the tree crops has a marked influence on the botanical composition and yield of forage (Wan Mohamed 1978, Chen and Othman, 1983). They reported a rapid decline in legume composition (except *Calopogonium caeruleum*) with age, and legume species accounted for less than 20% of the total dry matter yield when the tree crops were more than three years old. The standing dry matter biomass under rubber declined rapidly from 1600 kg/ha during the first two years to less than 600 kg/ha when the trees were 3–3.5 years old. These forage yields were much lower than those

reported earlier by Mahyuddin et al. (1978) and Devendra (1982) and need further verification under the variable agro-management, climatic and soil conditions that can be found under the plantations of Malaysia. There is also a need for an appropriate survey methodology which can be used to quantify the forage resources under rubber. These data can then be used as base data for the estimation of the sheep production potential under rubber.

This study reports the results of a survey of factors influencing forage yield and composition in the rubber plantations of the central region of Malaysia.

## Materials and Methods

The survey method adopted in this study of forage yield and botanical composition was a modified version of the Botanal method (Jones and Tothill 1985). Five rubber estates in the central region of Malaysia which did not raise sheep were selected for the survey. The estates were Sg. Rinching, Sg. Chinoh, Galloway, Bradwall and Sg. Jernih. At each site, the survey was conducted for 3 age groups of rubber: 1 – 2 years, 3 – 5 years and 6 – 10 years. Initially, a general view of the fields was obtained with the aid of field maps and the staff of the estates. A representative site was then selected. The survey was carried out with a series of 6 – 8 quadrats (1.0 × 0.5 m) taken across the rubber interrows in a band pattern. The bands were chosen every 10 trees in a systematic grid pattern. In each quadrat, the botanical composition was visually estimated and the relative yield was ranked between 1 and 10, based on

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the Botanal method where 1 = lowest yield, 5 = medium yield and 10 = highest yield. This ranking system was calibrated against quadrats which served as references and were subsequently cut at 2 cm above ground level, dried and weighed. Three recorders were involved who independently scored each quadrat. A total of 30 bands were ranked by each recorder. After sampling the field, each recorder cut a total of 20 samples to determine the relationship between yield and individual Botanal ranking. For each rubber age group, photosynthetically active radiation (PAR) readings were taken to determine the light transmission under the rubber trees. These readings were taken with two integrating PAR recorders, one outside the plantation in full light while the second was moved in a systematic pattern through the plantation. Integrated readings were taken over a 10-minute period between 1000 and 1400 hours.

## Site Description

The soil texture of the estates is as follows: Sg. Rinching (clay), Sg. Chenoh (clay/laterite), Galloway (clay/sandy clay), Broadwall (clay/laterite), and Sg. Jernih (clay, quartzite/laterite). The rubber clones were Sg. Rinching (RRIM 600, PB 235, 314 and 340), Sg. Chenoh (PB 260, 310 and 314), Galloway (PB 312, 235 and 260), Bradwall (PB 217, 260, 310, 311 338 and RRIM 600), Sg. Jernih (PB 255, 260 and RRIM 600). The planting distances between the rows varied from $6.3 \times 2.7$ m to $3.0 \times 8.0$ m for 1–2 years old rubber, $4.2 \times 4.2$ m to $5.7 \times 4.1$ m for – 5 years old

rubber, and $3.7 \times 4.8$ m to $4.0 \times 8.1$ m for 6-10 years old rubber. At these planting distances, the number of plants/ha for 1–2, 3–5 and 6–10 years old rubber were 417–588, 428–567 and 309–563, respectively. The mean girth of rubber trees at 127 cm above ground level for 1–2, 3-5 and 6–10 years old rubber was 8.4, 35.4 and 63.5 cm, respectively. Mean legume seeding rates planted in the interrows were 3.6 kg/ha of *Pueraria phaseoloides*, 1.6 kg/ha of *Calopogonium mucunoides*, 0.5 kg/ha of *Centrosema pubescens* and 0.6 kg/ha of *Calopogonium caeruleum*. The average annual rainfall varied from 1566 to 4232 mm/year.

## Results and Discussion

### Forage yield
The mean standing dry matter yield of forage (kg/ha) and PAR values in the interrows of the three age groups of rubber in the five estates are given in Tables 1 and 2 respectively.

The mean yield of forage was highest (2602 kg/ha) for 1–2 years old rubber while the lowest yield (537.5 kg/ha) was recorded for the 6–10 years old rubber.

The low yield under the 6–10 years old rubber was due to the closure of the canopy and the reduced light transmitted to the interrows. This was confirmed by the light transmission data which was 92% for 1–2 years old rubber and only 9% for 6–10 years old rubber. Forage yields obtained in this study were higher than the yields reported by Wan Mohamed (1978) for all age groups. The amount of forage

**Table 1.** Standing forage dry matter yield (kg/ha) in three different age groups of rubber.

| Age of rubber (years) | Estates | | | | | Mean | S.E. |
|---|---|---|---|---|---|---|---|
| | Sg. Rinching | Sg. Chinoh | Galloway | Bradwall | Sg. Jernih | | |
| 1 – 2 | 3250 | 2493 | 2974 | 2323 | 1970 | 2602 | 228 |
| 3 – 5 | 2080 | 995 | 1187 | 1032 | 940 | 1247 | 212 |
| 6 – 10 | 700 | 694 | 432 | 324 | 470 | 524 | 95 |

**Table 2.** Photosynthetically active radiation (%) in three different age groups of rubber.

| Age of rubber (years) | Estates | | | | | Mean | S.E. |
|---|---|---|---|---|---|---|---|
| | Sg. Rinching | Sg. Chinoh | Galloway | Bradwall | Sg. Jernih | | |
| 1 - 2 | 85 | 89 | 93 | 94 | 99 | 92 | 1.4 |
| 3 - 5 | 31 | 27 | 16 | 15 | 19 | 21 | 1.7 |
| 6 - 10 | 14 | 8 | 6 | 9 | 12 | 10 | 0.9 |

present in the different age groups of rubber will determine the potential stocking rate per unit area under rubber. However, it must be emphasised that these yields are of standing biomass only and do not reflect the potential yield of regularly defoliated herbage which would be higher in young rubber.

## Forage composition

Details of the forage composition for the three age groups of rubber are given in Table 3. The main forage species in the 1–2 years old rubber, where light transmission was highest, were legumes, with only some grasses. The main species were the planted cover crops *Pueraria phaseoloides* (79%), the volunteer grass *Ottochloa nodosa* (7%), and *Paspalum conjugatum* (6%). In the second age group (3–5 years), the composition of forage species had changed and the proportion of the previously dominant legumes had declined, while the proportion of grasses and broadleafed species had increased. The main forage species in this age group were *Ottochloa nodosa* (28%) and *Calopogonium caeruleum* (25%). *Aystaysia intrusa* (11%) was dominant in one of the estates only. In the oldest age group (6–10 years), where the light transmission was low, the composition had further changed to broadleafed plants and grasses. The dominant plant species were ferns (41%), and the grass *Ottochloa nodosa* (20%). These forage species are known to be relatively shade-tolerant.

In the 1–2 years rubber, the legume *Pueraria phaseoloides* was the dominant species partly because the interrows of the five surveyed sites were sown with high seeding rates of this species (3.65 kg/ha). The *Pueraria phaseoloides* composition decreased quickly from 79% to 12% and 1% for 1–2, 3–5 and 6–10 year groups respectively. This was probably related to the decreasing light transmission due to the closure of the canopy as the rubber matured.

The more shade-tolerant *Calopogonium caeruleum* became the dominant legume species. The composition of *Calopogonium caeruleum* in the 3–5 year group was 25% while for the 6–10 years old was only 9%. The increase in the content of volunteer grasses and broadleafed species, as the canopy closed, was shown earlier by Wan Mohamed (1978). In mature rubber only shade-tolerant species were found and ferns dominated.

**Table 3.** Forage composition (%) in three different age groups of rubber

| Age of rubber (years) | Location (estates) | Grasses | | | Legumes | | Broadleafed Species | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Co | On | Pc | Cc | Pp | Asy | Mc | Fer |
| 1–2 | Sg. Rinching | 0 | 9 | 15 | 0 | 75 | 0 | 0 | 0 |
| | Sg. Chinoh | 1 | 14 | 12 | 0 | 68 | 1 | 1 | 0 |
| | Galloway | 0 | 3 | 2 | 0 | 94 | 1 | 0 | 0 |
| | Bradwall | 1 | 5 | 0 | 1 | 77 | 1 | 0 | 0 |
| | Sg. Jernih | 0 | 5 | 1 | 0 | 80 | 1 | 3 | 0 |
| Mean | | 1 | 7 | 6 | 0 | 79 | 1 | 1 | 0 |
| 3–5 | Sg. Rinching | 0 | 16 | 5 | 33 | 3 | 10 | 21 | 1 |
| | Sg. Chinoh | 0 | 48 | 0 | 34 | 1 | 0 | 3 | 1 |
| | Galloway | 0 | 35 | 2 | 0 | 46 | 0 | 15 | 0 |
| | Bradwall | 3 | 18 | 4 | 4 | 10 | 5 | 4 | 0 |
| | Sg. Jernih | 2 | 22 | 2 | 7 | 2 | 39 | 12 | 13 |
| Mean | | 1 | 28 | 2 | 25 | 12 | 11 | 11 | 3 |
| 6–10 | Sg. Rinching | 45 | 17 | 8 | 8 | 0 | 2 | 4 | 11 |
| | Sg. Chinoh | 2 | 36 | 2 | 22 | 0 | 0 | 2 | 27 |
| | Galloway | 9 | 44 | 6 | 2 | 6 | 19 | 1 | 2 |
| | Bradwall | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 87 |
| | Sg. Jernih | 3 | 1 | 8 | 0 | 1 | 0 | 1 | 80 |
| Mean | | 12 | 20 | 5 | 9 | 1 | 4 | 1 | 41 |

Asy = *Asystasia intrusa*
Cc = *Calopogonium caeruleum*
Co = *Cyrtococcum oxyphyllum*
Fer = Ferns

Mc = *Mikania micrantha*
On = *Ottochloa nodosa*
Pc = *Paspalum conjugatum*
Pp = *Pueraria phaseoloides*

Note: Minor species not included in Table.

## Botanal method

The correlation coefficients between the Botanal ranking scores and forage dry weight in the three rubber age groups were highly significant. The Botanal visual ranking method was therefore appropriate for the determination of forage yield under rubber. The experience obtained in using the method can be adopted in the survey of forage resources in other perennial tree crops.

## Conclusion

The study of the forage resources under three age groups of rubber (1–2 years, 3–5 years and 6–10 years) in five estates in the central region of Malaysia has quantified the standing biomass yields of forages under different light transmissions. The amount of forages available will determine the stocking rate per unit area at the different ages of rubber that can be sustained.

There was a succession of plant species as the rubber canopy closed. *Pueraria phaseoloides* was the dominant species in the interrows during the first 1 to 2 years. As the canopy closed and shade increased (3 - 5 years old rubber), the amount of standing forage declined. The dominant plant species were mainly volunteer grasses (*Ottochloa nodosa*), planted legumes (*Calopogonium caeruleum* and *Pueraria phaseoloides*) and broadleaved weeds (*Mikania micrantha* and *Aystaysia intrusa*). The potential for animal production is therefore greatest during the immature period because of the higher forage dry matter availability at this time. It will be a challenge to introduce higher-yielding cultivated pastures into the rubber interrows which will be productive at lower light intensities. More studies are recommended to identify suitable forage species which have a high production potential and are able to sustain regular grazing in shaded environments.

The Botanal method used in this study was a useful technique. Using this method, we were able to record large numbers of samples in the field for yield and botanical composition as compared to the conventional system of cutting and weighing quadrats. The technique can be adopted for surveying forage resources under other plantation crops such as oil palm and coconut. Surveys of this nature are expensive in terms of labour requirement and time, and need to be well planned with objectives well defined. However, the baseline data obtained will be a useful guide for estimation of the animal production potential under different plantation crops and management systems.

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